MANUAL OF BOTANY.

BOTANY

A CONCISE MANUAL FOR STUDENTS OF MEDICINE AND SCIENCE.

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WITH ONE HUNDRED AND SIXTY-FOUR ILLUSTRATIONS AND A SERIES OF FLORAL DIAGRAMS.

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PREFACE.

It has always been my belief, rightly or wrongly, that a text-book for the student should be more or less in the shape of concise notes and summaries.

No one attempts to teach himself science now-a-days; all wisely attend lectures and demonstrations, where the principles are discursively set forth, and the details of structure, function, and classification exhibited and explained.

The modern student, therefore, does not so much require a manual, with diffuse explanations, but rather a kind of illustrated digest and general note-book, which will enable him to quickly arrange and make the most effective use of the various facts and theories treated of by his teacher. This little work is an attempt to construct such a useful text-book for learners, who are, or have been, members of a class in Botany.

The curriculum of Edinburgh University, where Botany is so well taught under Professor Balfour, has been closely, but not slavishly, followed throughout; and the book has also, as far as possible, been adapted to the requirements of the students of London University, Royal University of

Ireland, and the other Universities and Schools of Medicine, Pharmacy, and Science, in the United Kingdom, and also of the Science and Art Department.

I beg to acknowledge my indebtedness to the lectures and works of Professors Balfour, Bower, Scott, and M'Alpine, and to the text-books of Prantl, Goebel, Sachs, De Bary, Vines, &c. &c.

ALEXANDER JOHNSTONE.

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MANUAL OF BOTANY.

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INTRODUCTION.

NATURAL BODIES are either ORGANISED or UNORGANISED. The ORGANISED substances are those which are alive, or which by their structures show that they have once been the tenements of life.

What is Life?

Life is a series of complex actions, the most fundamental and essential of which are the processes of growth, respiration, circulation, digestion, and reproduction. The vital substance on the activity of which all these actions depend, and their source, is protoplasm, either in a simple or more or less modified condition. This living protoplasm, which will be more properly considered hereafter, is as yet an incomprehensible mixture of unknown chemical compounds, which are continually undergoing oxidation and deoxidation, and the consequent alternate building up and the breaking down of their constituent molecules gives rise to all the varied phenomena of living things, and is in itself the simplest kind of life.

CHARACTERISTICS OF LIVING THINGS.

1. They contain protoplasm.
2. They possess metabolic power, *i.e.*, they continually use up and renew the materials composing their bodies.
3. They grow and respire.

4. They undergo cyclical changes, *i.e.*, have a life history. To illustrate this point, take the case of any ordinary flowering plant:—

(1.) It begins life as an embryo.
(2.) The embryo passes into the adult state by the full development of root and shoot systems.
(3.) The mature plant produces flowers, from a certain portion of which, by special processes, seeds are elaborated, and every properly developed seed contains an embryo.
(4.) From the embryo the above stages are again evolved.

BIOLOGY is the science of living things, or things which have been alive, as shown by their structures. It is divided into—

1. Botany, which treats of plants.
2. Zoology, which treats of animals.

What is a Plant?

No definition can be given that will include the whole kingdom of vegetables. The highest kind of plants possess chlorophyll (green colouring matter), manufacture cellulose, and build up their other organic compounds out of inorganic materials. No animal in a healthy state can so elaborate its organic bodies. It requires to get them ready made. The lowest plants, however, on the whole so closely resemble the lowest animals that we cannot by the mere study of their forms decide whether they are plants or not, but by carefully considering the *connecting links* between those lowest beings and the higher organisms, we can determine their position by observing whether they lead up to forms possessing an undoubted nervous system (higher animals), or to fixed manufacturing forms (higher plants).

Definition of Botany.—The science which has plants for its subject, and which seeks to observe the phenomena of their structure and life, as well as their relations to one another and to the outer world.

The Science of Botany has five departments :—

1. Vegetable morphology (gross anatomy), and Histology (minute anatomy).
2. Vegetable Physiology.—The study of the functions of vegetable organs and life, including Reproduction and Embryology.
3. Taxonomy, or the classification, and Ætiology, or the uses of plants.
4. Geographical Botany, or the distribution of plants in space.
5. Palæontological Botany.—The study of fossil vegetables.

VEGETABLE MORPHOLOGY AND HISTOLOGY.

The Cell,

Or Unit in Vegetable Anatomy.

A multicellular plant (such as any of the higher vegetables) may be likened to a mansion with a great number of rooms, each constructed and furnished according to the use or function to which it is adapted and destined. Between contiguous apartments in a house there is a *single* or *common partition*, and between any two neighbouring cells in a plant, in like manner, there is but *one common wall.*

All plants alike at the very beginning of their existence consist of a single cell, but later on they either form tissues composed of many cells, or remain unicellular.

Examples of Mature Unicellular Plants.—Diatoms, Bacterium, Protococcus, Mucor, Vaucheria, Botrydium, Caulerpa, Pythium, &c.

Multicellular plants are aggregates of cells with common walls.

Example.—Fern, Elm, Lily, &c. &c.

Multicellular plants are either of *high* or of *low* organisation. In the latter there is only at most, in the mature forms, *slight* differentiation of cells, while in the former distinct and well marked differentiation occurs.

Examples of Multicellular Plants of Low Organisation.—Spirogyra, Fucus, Polysiphonia, Agaricus, Collema, Eurotium, Marchantia, Funaria.

Examples of Multicellular Plants of High Organisation.—Aspidium, Equisetum, Selaginella Pinus Capsella, Helianthus, Ulmus.

Parts of a Typical Mature Living Cell.

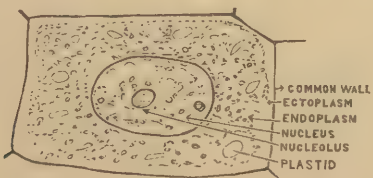
1. *Cell Wall.*—Firm, elastic, colourless.
2. *Contents*: *a.* & *b.*—Protoplasm with its nucleus,* the former lining internal part of cell-wall.
   c. Watery sap (cell sap) diffused through *a* and *b* and collected in the centre of the cell into one or more cavities (*vacuoles*) of the protoplasm.

Through the protoplasm are also scattered modified grains of that substance (*plastids*) and foreign matters, such as food granules, &c.

Life-History of any Cell.

1. It originates from another (*living*) cell.
2. It grows, becomes mature, and multiplies.
3. Its activity diminishes, and it ultimately dies.†

All the cells of a plant are at first practically, if not precisely identical,‡ but they soon become variously modified to a greater or less extent in groups, one set of



LIVING CELLS.

FIG. 1.—Young (initial) cell from apex of root of Fritillaria. × about 5000 times.

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* When a living cell is exceptionally large or extended it usually contains many nuclei, *Ex.* Mucor.

† A dead cell is often of great use to the plant for skeletal, protective, or other purposes. An old or dead cell *has no protoplasm*.

‡ All cells at first consist of two parts only—Protoplasm with nucleus, filling up the whole interior, and cell wall, rarely of one part only; Protoplasm with or (*very rarely*) without nucleus.

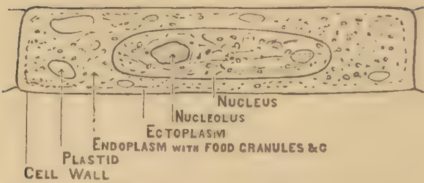

FIG. 2.—Initial cell from Cambium of Dicotyledon. × 6000.

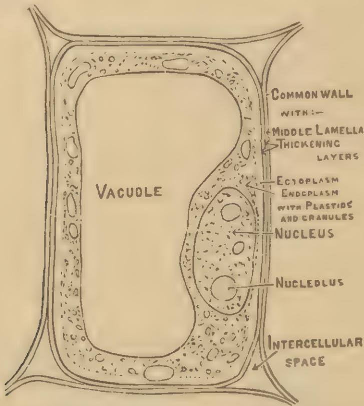

FIG. 3.—Mature living cell. × about 800 diameters.

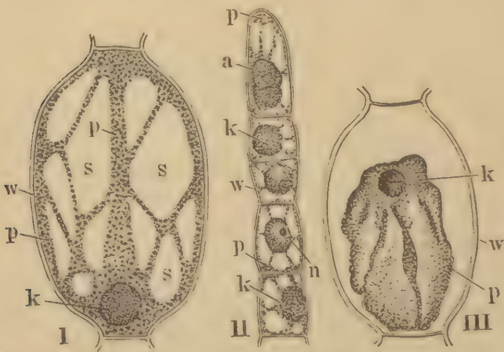

FIG 4.—Cells from the staminal hairs of *Tradescantia virginica.*—I. Full-grown cell; II. End cells of a very young hair; III. Old cell after treatment with alcohol. *w* Cell-wall, *p* Protoplasm, *s* vacuoles, *k* Nucleus, *n* Nucleus in act of division; × 600 times. (After Behrens.)

cells becoming adapted to perform one function more particularly, and another set to carry on a different duty.

The mature and old cells are generally elongated in the direction of the stems and roots of the plant. Exceptions:—Second medullary rays, &c.

Protoplasm, *or Vital Substance.*

Composition.—Protoplasm is a mixture of various kinds of albuminoids (proteids) with water, and a trace of mineral matter or ash. The elements composing the proteids are C, H, O, N, and S, and P,* the two latter (and especially the last) in very small proportion.

Physical Characters.—Soft, more or less viscid, semi-fluid (but never fluid), colourless, and in appearance rather like soft boiled sago, or the raw albumen of a hen's egg. With the lower microscopic powers it appears homogeneous and transparent, but when highly magnified is seen to be more or less granular, in consequence of the presence of numerous very minute solid nutritive bodies (microsomata) or drops of oil.

Chemical Characters.—Living protoplasm is either neutral or gives a slight alkaline reaction. It will not normally absorb aqueous solutions of colouring matters, nor allow even their passage through it, but *when dead* it has no power to hinder the diffusion of these materials, and becomes readily stained by them. Protoplasm is usually killed and coagulated at a temperature of about 50° C., or when alcohol or dilute mineral acids are added to it.

Structure.—The protoplasm of a cell is differentiated into two parts:—

1. *Endoplasm.*—The general internal *granular*, and by far the greater portion of the protoplasm. The innumerable minute granules are called *microsomata*.
2. *Ectoplasm.*—The *very thin*, delicate, *non-granular* † layer lining the cell wall. It shades off quite gradually into 1.

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* Those symbols stand for carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus respectively.

† A granule here and there may be seen occasionally in the ectoplasm, but compared to the endoplasm it is clear and homogeneous.

When dead the endoplasm stains much more deeply with colouring fluids than the ectoplasm, and when carefully examined it is observed that the staining is practically confined to *anastomosing fibrillæ* in the substance of the endoplasm and to the microsomata.

Movements.—The substances of all living protoplasms have in common throughout life the movements 1, 2, and 3, though in some either 1 or 2, or both, may be obscure; 4 and 5 are peculiar to wall-less protoplasm.

1. *Circulation.*—Movement of the granules, &c., to and from the nucleus. This motion is very well shown in the hairs of the stinging nettle.
2. *Rotation.*—Movement of the substance of the protoplasm round and round the cell-wall. Is well marked in the cells of Vallisneria and Chara.
3. *Contraction* and other movements due to the irritant action of strong light, touch of foreign bodies, pressure, electricity, heat, &c.
4. *Ciliary.*—Vibratile movements of prolongations of the ectoplasm.

   Examples.—Antherozids, (spermatozoids), Zoogonidium of Vaucheria, &c.

5. *Amœboid.*—A movement by which the naked mass of protoplasm continually changes its outline by the formation and withdrawal of blunt protrusions of its substance.

   Example.—Myxomycetes (during its amœboid stage).

Physiological Properties of a Living Cell.

A cell which contains protoplasm carries on osmotic and metabolic processes (respiration, assimilation, digestion, circulation, excretion, &c.), is irritable, can convey impressions of stimuli to a greater or less extent, and is capable of growth, of forming new cells, and elaborating new chemical compounds.

The protoplasm of one cell of a plant is in some way not yet properly understood connected with the protoplasm of every other living cell in the same vegetable.

Substances in Protoplasm.

Nos. 1 *and* 2 *are vital substances;* 4, 5, *and* 6 *are known as nutritive, plastic, or formed substances.*

1. *Nucleus*—Is the governing portion of the protoplasm. There is usually one in each living cell, but in greatly elongated or branched cells, or non-septate organisms, like Vaucheria, there are generally many nuclei. In a few rare cases, *e.g.*, Bacteria, nuclei have not been found at all in the cell.

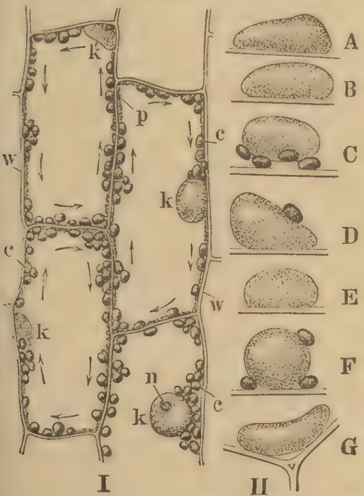

FIG. 5.—I. Cells with rotating protoplasm from a leaf of *Vallisneria spiralis*. *w* Cell membrane, *p* Protoplasm, *c* Chlorophyll granules, *k* Nucleus, *n* Nucleolus. (The arrows show the direction in which the protoplasm moves in each cell.) II. Nucleus from the upper cell to the right. *A G* Different forms assumed by the nucleus during twenty-six seconds. I. × 600 times; II. × 1000 times. (After Behrens.)

The nucleus, which is somewhat ovoid in form, is always embedded in protoplasm. It contains granules, the largest of which is termed the *nucleolus*. The nucleus, which is soft and plastic, occupies a large portion of the interior of *young cells* owing to the relative smallness of their cell cavities.

2. *Plastids.*—Usually little round, ovoid, cylindrical, or spindle shaped proteid bodies, having the same physical and chemical properties as the protoplasm, but clearly differentiated from it by some specialization in order to enable it to perform one or more important vegetative functions.

3. *Colouring matters.*—Usually in certain of the plastids which, when coloured, may be called *chromatophores*. Coloured plastids occur in parts well exposed to light, as foliage and floral leaves.

4. *Starches and carbohydrates* in general.

5. *Fats* and Oils.*—In seeds such as castor oil, linseed (flax), &c. In Spirogyra, Fungi, &c. &c.

6. *Nutritive Albuminoids* or *Proteids.*—Composed essentially of the elements C, H, O, N, S, with or without a trace of P.

7. *Cell Sap*, *i.e.*, Water with mineral and organic matters in solution.—This saturates and pervades the whole organic structure of the living cell. It usually (*always* in mature cells) also collects in the interior of the protoplasm, so as to form vacuoles, or a single large *vacuole* or *sap cavity*. The protoplasm at first fills the cell completely; its *vacuolation* is due to the growth of the cell wall, to which the main body of protoplasm adheres. The cell sap frequently contains colouring matters.

Note.—Distinguish carefully between the colouring substances of the plastids, and those found in solution in the general body of the sap of certain cells which may or may not contain protoplasm.

The Nucleus.

Shape.—Spherical or ellipsoidal with a definite outline. It changes its form slightly at different times.

Occurrence, &c.—Always *in* protoplasm, of which it is generally regarded as a specially differentiated part, differing from the rest of that material in its greater density, and in other respects. It, however, always *originates from a pre-existing nucleus*, and never from the ordinary protoplasm† of the cell.

Number.—Usually one in a cell (see page 9).

Function.—The specially governing part of the cell: is intimately concerned with cell formation, and with the processes of reproduction, &c. &c.

Chemical Characters.—When living it resists, like the protoplasm in which it is embedded, the entrance of colouring agents, but when dead is at once stained by

* Vegetable wax is closely related to the fats.

† The *first* nucleus in the vegetable kingdom therefore must have been specially created.

them. It usually stains deeper than the surrounding protoplasm, because it is richer in albuminoid matters.* Its proteids contain a trace of phosphorus.

Structure.—It consists of—1. *Nucleoplasm* or nuclein (comparable to protoplasm) which is composed of anastomosing strands of clear or *hyalo-plasm*, with embedded granules, which are termed nucleo-microsomata or nucleo-macrosomata according to relative size, the largest granule of the latter sort being called the *nucleolus* †; 2. of *nuclear sap* in the meshes of 1 (which acts as the framework of the nucleus); and 3. of a nuclear membrane that forms the limiting boundary of the whole body.

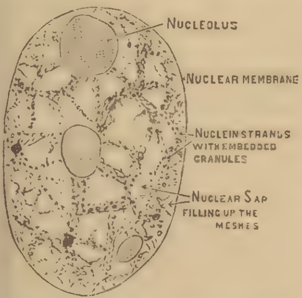

FIG 6.—The Nucleus (diagrammatic); very highly magnified.

Multiplication.—The nucleus multiplies itself either by *karyokinesis* (usual method) or (in multinucleate single cells) by *fragmentation* (see page 27.)

PLASTIDS.

These are peculiar vital proteid bodies of various shapes embedded in greater or less numbers in the general protoplasmic mass of every active cell, and not separable from it by any mechanical means. Like nuclei they never originate *de novo* from the protoplasm but always from pre-existing plastids. They multiply by fission (fragmentation). At the beginning, all plastids are colourless and similar, but three types of mature forms can be recognised.

Kinds.—1. LEUCOPLASTID (the *original type*)—Colourless, or rarely *very* faintly tinged with yellow. Its function is

* The portion which stains by far most distinctly and deeply is the nucleoplasm or chromatin (see below); the nuclear sap, which practically remains unstained, is on this account often called achromatin.

† The nucleolus appears as a swelling on a fibrilla of the network. When two or more granules appear very conspicuous they are all termed nucleoli.

mainly to form starch from sugar. It is very minute, and is said to have a porous or spongy body. Leucoplasts are found in white, or colourless portions of plants which store up starch, &c., in young cells,* in ova, &c. Leucoplasts become chloroplasts by the development of chlorophyll, or chromoplasts by the production of a yellow or *rarely* red pigment.

2. CHLOROPLASTID, *or chlorophyll granule.*—In all the higher plants is more or less round, but in the lower organisms, *i.e.*, Algæ, may have various shapes. Its distinguishing characteristic is its green pigment (chlorophyll); and it is to the presence of innumerable chloroplasts that the green colour of the leaves of ordinary plants is wholly due. They are, however, sometimes masked by coloured cell sap, or they may become brown or red by a peculiar modification of their chlorophyll pigment.

Chloroplastids frequently become of considerable size, owing to the presence of solid contents (starch, &c.) which they elaborate from CO_2 and H_2O in the presence of sunlight.† When treated with alcohol, which removes the chlorophyll, the structure of this plastid can be made out after staining with iodine, by using a very high power. It is seen to have a spongy or trabecular structure, especially towards the exterior, and normally the chlorophyll pigment appears to be contained in the interstices of these trabeculæ.

Chloroplastids are only found, as an almost invariable rule, on parts exposed to light,‡ but they are altogether absent from fungi (except in a very few rare cases), complete parasites, and saprophytes. Their function is primarily the elaboration of starch ‖ from CO_2 and H_2O, but they also in some manner, not yet comprehended, undoubtedly manufacture nutritive proteids. They spring from the original colourless plastids (leucoplastids?) of the young cells, and when mature take up certain alternating

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* In the youngest cells, for instance those at the growing apex of stems and roots, all the plastids are leucoplastids, or perfectly similar to these in appearance, structure, &c.

† The starch is sometimes found on the *exterior* of the chloroplasts forming noticeable protuberances.

‡ Certain plants, however, notably the seedlings of Pinus, can develop a bright green colour in the deepest darkness.

‖ Or rarely fats or oils as in some Algæ (*e.g.*, Vaucheria and Spirogyra).

positions in the cells they inhabit, determined by the amount of light present.

When kept for a lengthened period in darkness the colour of the plast changes to yellow, and if the change

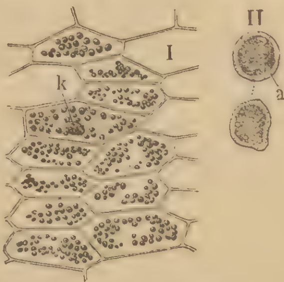

FIG. 7.—Cells with chlorophyll granules.—I. From the leaf of *Marchantia polymorpha*; × 200 times. II. Do. single granules; × 900 times. (After Behrens.)

is not arrested at this point by again illuminating with daylight, the plastid will either break up and apparently

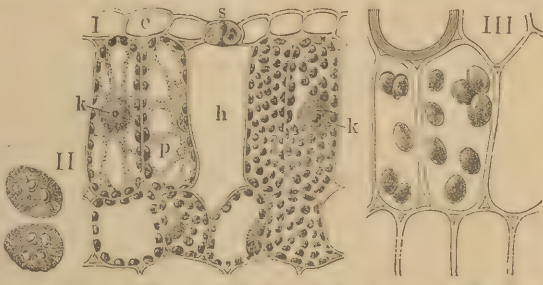

FIG. 8.—Cells with chlorophyll granules.—I. From the leaf of the garden bean (*Vicia Faba*); × 300 times. II. Do. single granules; × 900 times. III. From the leaf of a banana (*Strelitzia Nicolai*); × 300 times. *k* Nucleus, *p* Protoplasm, *a* Starch granules, *e* Epidermis, *s* Stoma, *h* Air-space (see p. 42). (After Behrens.)

become merged in the protoplasmic mass of the cell, or totally lose its colour and become in appearance similar to a leucoplastid.* In some of the simplest

* Certain plants, however, notably the seedlings of Pinus, can develop a bright green colour in the deepest darkness.

Algæ (*e.g.*, Protococcus), the chlorophyll is *diffused* through the whole protoplasm. The autumnal colours of leaves are due to the metamorphosis of the chlorophyll.

3. CHROMOPLASTID.—Plastids with colouring matter other than chlorophyll are chromoplastids. The colour which they carry is almost invariably yellow (but may be red), and it is to those chromoplasts that the tint of yellow petals, &c., is due.* Their function is ornamental (for attraction of insects, &c.), and they occur in flowers and certain fruits.

STARCH.

This is the chief form in which the elaborated food of ordinary plants is held in reserve. It always occurs in the solid state, and usually as minute † spheroidal or polyhedral grains, but may be lenticular or dumb-bell shaped (Euphorbias), &c.

Composition.—Every grain is composed of the chemical compounds, starch and water, and the merest trace of mineral matter (ash). The starch substance is of two kinds:—*Starch-granulose* ‡ and *Starch-cellulose*, which are mixed together through the grain. The former can be extracted by saliva or dilute acids, while the latter, which forms only from two to six per cent. of the whole, remains as the skeleton of the grain. Starch-granulose becomes blue when treated with iodine.

Kinds of Starch Granules.—1. Simple; 2. Compound; both usually occurring in the same cell.

Structure.—The substance of the starch-grain is disposed in more and less watery *layers* round a darkish point or *hilum*, the most watery portion of all. The hilum is centrally (*e.g.*, wheat) or excentrically placed (*e.g.*, potato). When two or more hilums are present the grain is said to be *compound*. Grains which have become adherent by mutual

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* Other colours of flowers and fruits, except white, are due to coloured sap. White comes from the total reflection of light from empty cells. The red tints are occasionally due to red chromoplasts.

† Some large granules, however, are just distinguishable as granules to the naked eye in the potato, curcuma, &c.

‡ Granulose constitutes the starch proper.

pressure are *spuriously compound.* The starch granule grows by *accretion** under the direct influence of a plastid or plastids.

Occurrence.—They are found in all plants with chloroplasts, *i.e.*, all except fungi and other parasites and saprophytes. They primarily originate in the interior or under the influence of chloroplastids.

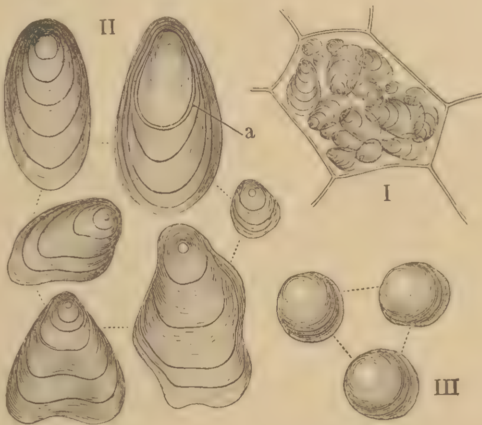

FIG. 9.—*Starch Granules.*—I. Parenchyma cell from the tuber of the potato (*Solanum tuberosum*) crowded with starch granules; × 150 times. II. Single granules from the same cell, showing the laminæ (at a crack); × 600 times. III. Starch granules from the endosperm (albumen, comp. p. 70) of wheat (*Triticum vulgare*); × 600 times. (After Behrens.)

Formation.—1. In the chloroplasts by elaboration or so-called assimilation from carbonic acid gas (CO_2), and water (H_2O), in the presence of sunlight, according to the following equations:—

(*a.*) $6\,CO_2$	+	$6\,H_2O$	=	$C_6H_{12}O_6$	+	$6\,O_2$
Six molecules of CO_2	and	six molecules of H_2O	give	one molecule of Glucose or grape sugar.	and	six molecules of oxygen gas which are evolved.

* That is, by the addition of new matter on the *outside* of old matter.

(*b.*) $C_6H_{12}O_6 \quad - \quad H_2O \quad = C_6H_{10}O_5$

i.e. By *dehydration* one molecule of Glucose *loses* one molecule of water and becomes Starch.

2. From sugar solutions by the action of the leucoplasts in storing cells.

Functions.—Starch acts directly as nutritive material (after digestion and consequent conversion into some kind of sugar), as a reserve nutritive material, as a fat former in certain plants, and indirectly in the formation of nutritive proteids.

Life History of a Starch Grain.

1. It is created by elaboration (as above) in the interior of a chlorophyll plastid.
2. Grows by accretion.
3. It is removed in solution (as sugar) and at once used as a food, or stored away, as a reserve product after reconversion into starch by the leucoplasts in certain living cells, or as sugar in living or dead cells.
4. In the living storing cells the starch grains are from time to time digested and transported when and to where they are required as food material.

Note.—For the other carbohydrates, which are all soluble in water see under cell-sap below.

Fats and Oils.

Composition.—The oils are usually free fatty acids* (stearic, palmitic, oleic), but most of the fats appear to be mixtures of the three kinds, stearin, palmatin, and olein.

Formation.—1. From Starch, *e.g.*, Castor Oil plant.
2. From proteids by degradation.
3. Rarely as a direct assimilation (elaboration) product of the chloroplasts, *e.g.*, Vaucheria.

Occurrence.—In living or dead cells, where they show as

* The oils, however, form intimate mixtures with the proteids in many cases, *e.g.*, Ricinus.

little refractive globules that are blackened by the application of osmic acid. Oil drops are generally always present in the cells of Fungi, where they act as the form in which the essential carbon is chiefly stored.

Functions.—They serve as direct or reserve nutritive material.

Vegetable wax is closely allied to the fats.

Proteids (Nutritive).

These are either amorphous (*aleurone grains*) or crystalline (*crystalloids*). They act directly as food stuffs and likewise as reserve nutritive materials, and are stained by reagents in the same manner as dead protoplasm and plastids. The crystalloid is probably a purer albuminoid substance than the aleurone grain, but otherwise the characteristic appearance of each is the only apparent distinction between them.

Aleurone Grains.

Form and Nature.—Roundish granules of various microscopic sizes. They are large and conspicuous in oily seeds, and very minute in other cases where starch is the form in which the carbon is chiefly stored. They almost always enclose *globoids* (see under), and frequently crystalloids; but the two bodies named may occur quite separate from them. The former, however, appear to always accompany the aleurones and crystalloids in the same cell.

Occurrence.—Chiefly in seeds and tubers. The principal food materials in seeds are starches or oils (or both) and protein granules.

Crystalloids.

Form.—True crystals of albuminoid matter which differ physically from inorganic crystals merely in swelling up when treated with caustic potash. They often show zoning, or lines of growth, and almost always appear quite colourless. The following are the common crystalline forms assumed by these bodies:—

1. Cubes; 2. Octahedrons; 3. Tetrahedrons; 4. Rhombohedrons.

Occurrence.—Usually in the general body of the protoplasm or in aleurone grains. They are occasionally found, however, but rather seldom, also in the nucleus (*e.g.*, Neottia) or chromoplastids (Viola).

Formation.—By crystallisation from a state of solution of proteid (aleurone?) matter.

Globoids.

Very minute round concretions of the double phosphate of lime and magnesia. They always accompany the nutri-

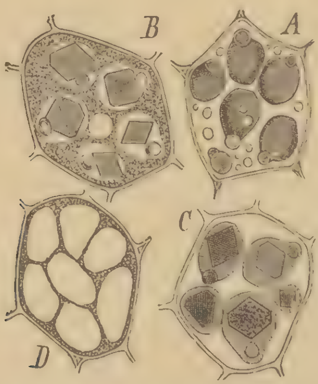

FIG. 10. Cells from the endosperm of *Ricinus Communis* (× 800), showing aleurone grains, crystalloids, and globoids. *A*, fresh, in thick glycerine; *B*, in dilute glycerine; *C*, warmed in glycerine; *D*, after treatment with alcohol and iodine; the aleurone grains have been destroyed by sulphuric acid, the matrix remaining behind as a net-work. In the aleurone grains the globoid may be recognised, and in *B*, *C*, the crystalloid. (After Prantl.)

tive proteids (at least in higher plants) and appear to have something to do with the getting of these into a state of solution when necessary.

Cell-Sap.

This is water with soluble mineral and organic compounds in solution. It frequently contains (as in petals of flowers) red, blue, violet, &c., colouring matters. It saturates the protoplasm of mature cells and fills the

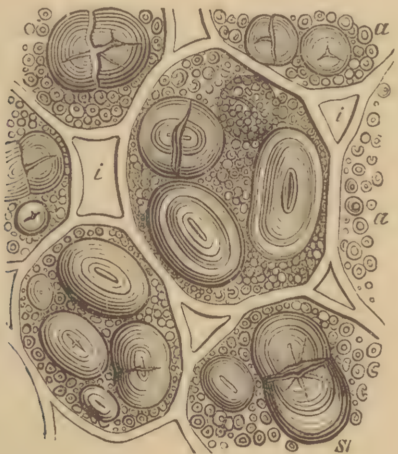

FIG. 11.—Cells of a very thin section through a cotyledon of the embryo in a ripe seed of *Pisum Sativum*; the large concentric-stratified grains, *St*, are starch-grains (cut through); the small granules *a* are aleurone, consisting of proteids; *i* the intercellular spaces. (After Prantl.)

vacuoles in its interior. In a cell in its initial stage there are no vacuoles; the protoplasm occupies every bit of the space within, but, owing to the great attraction of living protoplasm for water, and to its power of holding it, this soon gathers in the centre of the cell, pushing the protoplasm all round firmly against the walls which are then forced to expand or grow by intussusception, and as the growth proceeds the protoplasm continues to absorb more and more sap, the excess of which it, as before, stores up temporarily in its

interior. This is what is meant by the vacuolation of protoplasm.

Function of the Cell-Sap in Vacuoles.—It is the reservoir where the organised substances of the cell supply their wants. There also the excess of material, elaborated by the protoplasm, is dissolved and accumulated.

Substances Dissolved in Cell-Sap.—1. Mineral Substances (nitrates, sulphates, phosphates, &c.; the three mentioned are always present *). 2. Vegetable Substances (cane sugar, glucose or grape sugar, inulin,† tannin, organic acids,‡ colouring matters; some form of sugar and some organic acid or acids are always present).

Compounds of lime (usually calcium oxalate) occasion-

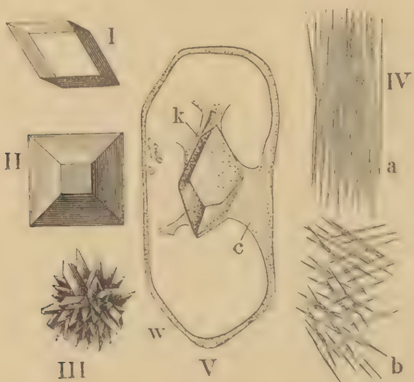

FIG. 12.—Crystals from vegetable cells: I. Of carbonate of calcium (rhomboidal). II., V. Of oxalate of calcium. II. Four to eight sided, with truncated ends. III. Crystal from the nectary of *Malva*; × 600 times. IV. *a b*, Crystals from the leaf of the fuchsia; × 450 times. V. Cell from the pulp of the rose fruit, in the centre a crystal (*k*), supported by bands of cellulose (*c*). (V. after Poulsen). (After Behrens.)

* Silica is dissolved in the cell-sap of most grasses and Equisetums, &c.

† A variety of sugar for nutrition is abundant in the root cells of Compositæ (daisy, dandelion, &c.).

‡ The organic acids are connected with the osmotic and metabolic processes of the growing cell.

ally crystallize out in the sap, forming single crystals or groups of crystals. When needle-shaped these bundles are known as *Raphides.*

Differentiation of Protoplasm into Cells.

Examples of WALL-LESS? *Protoplasm.*—Amœboid stage of Myxomycetes Spermatozoids. The first stage of every plant sexually produced.

Examples of WALLED *Protoplasm* NOT PARTITIONED *off into separate compartments or cells.*—Mycelium or vegetative part of Vaucheria, and of Mucor. Early stage of every plant.

When protoplasm, surrounded by a cell wall, becomes partitioned off by the formation of transverse and longitudinal common walls into distinct chambers it is said to be *differentiated into cells.* In all, except the very lowest *mature* plants, the protoplasm is so differentiated.

The Operations associated with Differentiation.—1. Division or Multiplication of the Nuclei; 2. Cell wall formation.

THE CELL WALL.

Formation.—The cell wall is produced from materials contained in and elaborated by the protoplasm,* and is formed, and continues to grow, in *intimate contact with it.* This contact is maintained by the turgidity of the cell. At first the wall possesses no evident structure, it is merely a membrane of cellulose, but latterly, by the processes of growth, it generally becomes differentiated into layers, so that we can recognise *striations.* Its consistence at the beginning is that of the most delicate cotton fibre.

Functions.—Protection; to form a skeleton; and to render the robust extension of the plant possible by the formation of a multicellular structure.

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* According to Schmitz the cell wall is formed by the conversion of the limiting film (ectoplasm) of protoplasm into cellulose, the material of the normal primordial wall. The only known reagent which can dissolve this cellulose without change of composition is the solution of cupric oxide in ammonium hydrate.

Composition of a young Cell Wall.—Cellulose mainly, with much water and a *little* ash (mineral matter).

Cellulose is isomeric with starch (*i.e.*, of same composition), but differs from that body in physical and other properties, and in its not being coloured blue by iodine alone, without previous treatment with sulphuric acid. The young or cellulose wall is almost, or quite, homogeneous: faintly striated; has an even surface; is very minutely porous (though these pores cannot be seen) for it admits fluids and gases, and permits of the *continuity of the protoplasm* of one cell with that of another by means of extremely delicate protoplasm (ectoplasm?) threads which pass through the intervening wall.

A cell which is actively living has a cellulose wall; and a cell can normally only grow *in size* if it possesses such a bounding structure. The cell wall, however, in time may become transformed into the isomers, cork, wood, or mucilage, and receive regular or irregular additions of those materials.

Growth of Cell Wall.—The growth in extent (*superficial growth*) takes place by *intussusception*, *i.e.*, by the *intercalation* of molecules of substance elaborated by the protoplasm, and accompanied by much water, between the pre-existing molecules of the cell wall. The subsequent growth in *thickness* of the wall appears to be effected almost entirely by *accretion* or ordinary deposition (see page 14).

Superficial Growth is either General or Local. When the former the cell retains its original shape: when the latter it alters its form, becoming elongated, armed, star-shaped, &c. &c.

Growth in Thickness is also either General or Local. When the former, the wall becomes uniformly thick and striated; when the latter, reticulate, annular, spiral, or spiked thickening may result, or minute, *thin*, round elliptical, or slit-like areas left, which are known as *pits* or canals. The pits on opposite sides of the common walls always correspond to and face each other.

Pits.—There are three kinds :—

1. *Simple* or Ordinary.

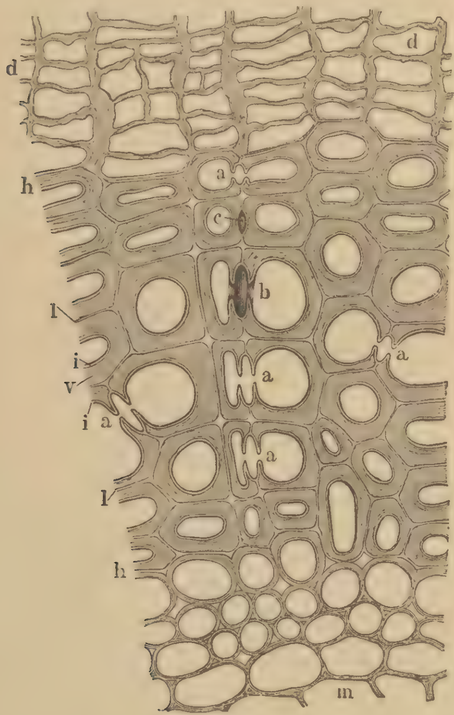

FIG. 13 —Pitted cells of a one-year-old stem of the yew (*Taxus baccata*). — Piece of the stem in transverse section ; × 1000 times. *h h* Wood cells, *m* Pith, *l* Middle lamella, *v* Middle lamina, *i* Inner lamina, *a a* Bordered pits cut across their longest diameter, *b* Do. showing underlying space, *c* Do. transverse section below the middle. (After Behrens.)

2. *Bordered.*—Round funnel shaped depressions, being narrowest at the top., *i.e.*, at the internal surface of the wall next the cell-cavity, and widest at the bottom.

These are very characteristic of the secondary wood-cells of the Coniferæ (pines, &c.)

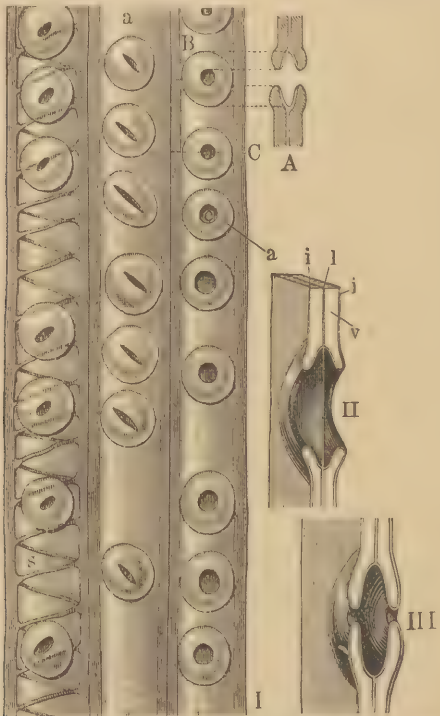

FIG. 14.—Pitted cells of a one-year-old stem of the yew (*Taxus baccata*).—I. Three wood cells in longitudinal section; × 1000 times. *a* Bordered pits with circular opening; *a'* Do. with slit-like opening. *A* Diagrammatic representation of pit *B* in longitudinal section. II. Diagrammatic representation of a young pit. III. Do. of an older pit; letters same as in Fig. 12. (After Behrens.)

3. *Scalariform.*—Just broadly elongated or narrow slit-like border pits, usually regularly and closely arranged together. Very characteristic of Ferns.

They often follow each other with as much regularity as the "rounds" of a ladder, whence the name *scalaria*, a flight of steps.

Modifications of the Cell Wall.

The original cellulose membrane and (*or*) the new cellulose, elaborated by the protoplasm as thickening matter, may become transformed, as already indicated, by *chemical metamorphosis*, or altered in physical nature by *infiltrations of mineral matter*,* or by *incrustations of carbonate of lime*. The corky, woody, and mucilaginous walls are produced by the first method.† In the second we find that the substances which are most commonly infiltrated into the wall (or left there by the evaporation or abstraction of the fluid which held them in solution) are silica, oxalate of lime (in barks of trees of many Gymnosperms) and carbonate of lime. A thickened internally protuberant part of the cell wall, containing carbonate of lime, is called a *Cystolith* (*e.g.*, leaf of indiarubber plant). The third mode of alteration ? is not common, and is confined to the external parts of green plants growing in water, containing carbonate of lime in solution. These various changes only take place when the protoplasm is of considerable age.

Special Functions of Common Kinds of Cell Wall.

1. *Cellulose Wall.*—Allows process of growth to proceed freely, being elastic and ductile, and easily permeable to sap.

2. *Corky Wall.*—Generally confined to superficial cells. Its purpose is to prevent evaporation of water.

3. *Woody Walls.*—Skeletal. They also aid the circulation of water by imbibition. Among aquatic plants wood is not formed, as in these cases it is not essential for either of the purposes named.

4. *Mucilaginous Walls.*—Are capable of absorbing and retaining a large amount of water. Are found in Fucaceæ (tangle, &c.), certain seeds, &c.

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* Or, as commonly happens, the mineral matter may be infiltrated into walls already transformed into wood, &c.

† Some botanists believe that corky and woody walls are formed upon, or, in the former case, infiltrated into the original wall, the cellulose nature of which persists with extremely little modification. It is certain that the parts of the thickened walls separating the pits of contiguous cells is of a cellulose character.

Formation of Cells.

The original naked mass of protoplasm is converted into a number of cells, first by the formation of a peripheral wall, and then, as growth goes on, of transverse and longitudinal walls by the process of cell-division, giving rise to a tissue with common partitions (*bipartition*), or to a mass of cells *free* from one another (*free cell-formation*). The division of the protoplasm and formation of the separating wall is preceded by the division of the nucleus.

Bipartition and Free Cell-Formation.—Before the production of the separating wall in bipartition, the nucleus goes through a process, leading to its ultimate division, known as *karyokinesis*. In free cell-formation the nucleus also divides in this way, the only essential difference between the two methods of cell-formation being, that in the former a multicellular structure, with *common* partitions, is erected, and in the latter, cells permanently or temporarily free from one another are produced.*

New cells are also formed by *Rejuvenescence* and *Coalescence*. In the former the entire protoplasm of the parent cell comes out in a naked condition, leaving the wall or framework of the empty chambers behind it. This wall-less mass ultimately, after swimming about for some time, elaborates a new peripheral wall for itself, *e.g.*, Zoogonidium of Vaucheria. By this method there is of course no increase in the number of cells.

In *Coalescence*, a new cell is produced by impregnation, or the blending of the elements of opposite sexes. The consequence of this process is a *diminution* in the number of cells. A male cell (spermatozoid) fuses with a female cell (ovum), and the result is *one* new cell (fertilised egg) with strong vitality and different (and altogether mysterious) physiological properties and powers.

* The term free cell-formation is also generally applied to a mere modification of bipartition in which the nuclei go on dividing for a time without forming separating partitions, until the protoplasm has been fairly portioned out, the common cell walls making their appearance later, *e.g.*, formation (or rather commencement of formation) of the Endosperm in the embryo sac of Phanerogams.

Multiplication of the Nuclei.

A plant when it begins life consists of one cell with one nucleus. From the latter all the nuclei required for the due government and direction of the increasing protoplasm of the expanding plant body is produced. Nuclear multiplication is accomplished either by—1. Direct division or *fragmentation*; or 2. Indirect division, or *karyokinesis*. The former is the usual method by which many nuclei are produced in *one* greatly expanded or developed *non-septate* cell, as Vaucheria; and the latter is always associated with and precedes bipartition and normal free cell formation.

Fragmentation.—The nucleus becomes simply constricted at the equator and ultimately separates into two nuclei, both of which, after growing to the size of their original, may divide in like manner, and so on again and again.

Karyokinesis.—The parts of the nucleus behave in the following manner before perfect division occurs:

A. Prokinesis.
(1) The *reticulate skeleton* of nucleoplasm breaks up and arranges itself
(2) into *spiral rods* which gradually make their way to the equator of the nucleus, where they straighten and group themselves
(3) in the form of a star (*aster*).

B. Dyaster.
(4) Afterwards the rays of this star split longitudinally, and two stars (*dyaster*) are formed, which gradually move away

C. Metakinesis.
(5) from one another to the poles of the nucleus where their constituent
(6) parts separate into *spiral rods* (see (2) above), that eventually join, forming at each of the
(7) old nuclear poles a *reticulated skeleton* (see (1) above) of nucleoplasm.
(8) Those polar skeletons, by the attraction and holding of nuclear sap and formation of nuclear membranes, eventually constitute *two distinct nuclei.*

The Nuclear Spindle.—While karyokinesis is proceeding, the membrane of the nucleus, at any early stage, dissolves up and disappears, and the surrounding protoplasm moves in and mixes with the nuclear sap. The invading protoplasm then becomes arranged in the form of rods, which taken together have a spindle or barrel-like appearance (*the nuclear spindle*). The ends of this spindle correspond to the poles of the original nucleus, and its rods act as guiding strands along which the nuclear stars (at Dyaster period) move away from each other to these extremities.

The Cell Plate.—At the equatorial portion of the spindle, in the process of bipartition, after the stars have slipped along to the polar areas, bead-like thickenings, due to the gathering of microsomata,* appear. These stretch in a row from wall to wall of the original cell, and constitute the *cell plate*, which shortly afterwards becomes properly filled up and developed into a common cellulose wall of separation between the now two distinct cells.

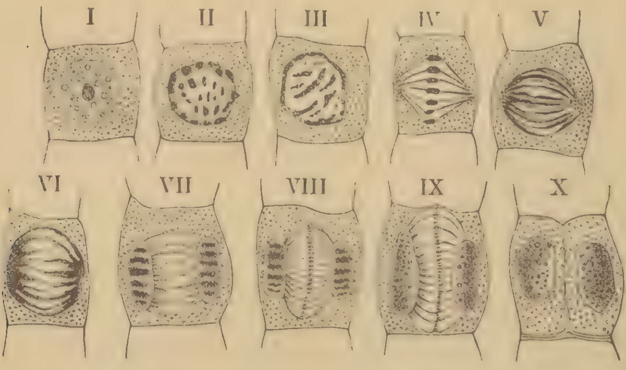

FIG. 15.—*Cell-division.*—Origin of guard-cells of the stomata in the leaf of *Iris pumila* (for explanation see text). × 880 times. (After Strasburger.)

* Of a carbohydrate nature.

Directions of development of cells.

There are two types of growth: that which takes place without cell division as in some low plants, such as Mucor, Pythium, Vaucheria, &c., and that which is always accompanied by cell division.

Growth with Cell Division.—This gives rise to tissues of various kinds:—

1. *Cell Row.*—Produced when the growth, which is mainly in length, is accompanied by the creation of *transverse* walls only.

   Examples.—Œdogonium, Spirogyra, many hairs, &c.

2. *Cell Surface.*—When the growth is greatly in breadth as well as in length, and is accompanied by the formation of both new transverse and longitudinal walls.

   Example.—Ulva.

3. *Cell Mass.*—When the growth is distinctly prominent in breadth and thickness as well as in length, and is accompanied by the formation of *two sets* of longitudinal as well as transverse walls.

   Example.—All the higher plants.

Phases of Growth.

1. The initial or dividing phase, when growth of the cells is accompanied by cell division. The cells in this stage are known as *initial cells.* These are found normally at the apex of the stem, and at the growing apex of the root behind the root cap where they constitute the *apical meristem;* or are *intercalated* between permanent cells (as the cambium layer of Dicotyledons and Gymnosperms which lies between the wood and the bast), or are lateral or basal.

2. The lengthening and enlarging phase.

3. The permanent phase.

Note.—The only *primary* initial cell is of course the fertilised egg or ovum, or (in the lowest plants) its asexual equivalent.

Types of Cell Branching.

1. *Monopodial.* 2. *Dichotomous.*

In the first class, which is the typical case, the branches are produced from *lateral* initial cells, while in the second they arise from *apical* initial cells.

Branches produced from an Axis.—The axis (or parent portion) may remain unbranched as in Spirogyra, or produce *one* branch when it is said to be *uniparous*, or *two* (*biparous*), or three or more (*multiparous*).

CELL BRANCHING.

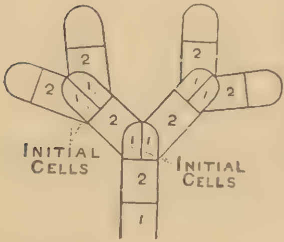

FIG. 16.—Equal Dichotomy.

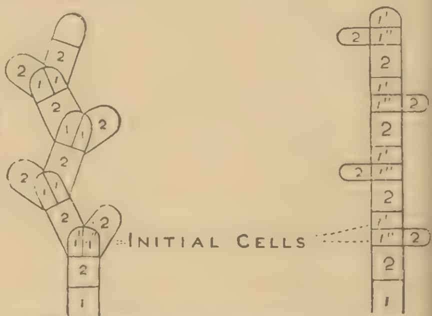

FIG. 17.—Sympodial (Scorpioid) Dichotomy.

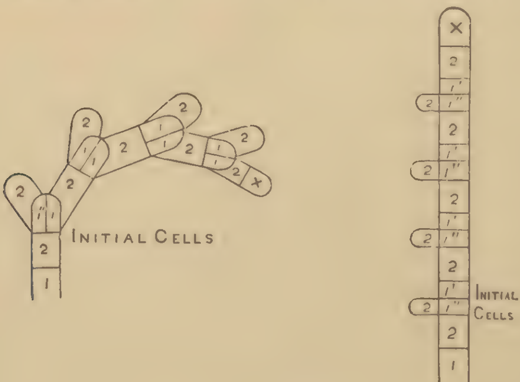

FIG. 18.—Sympodial (Helicoid) Dichotomy.

Dichotomous Branching:—

1. *Equal.* When the branches are equally developed.

2. *Sympodial.*—When at each branching one member becomes much more strongly developed than the other, "in such a case the bases of the successive bifurcations appear to constitute an axis, called the false axis or sympodium, on which the weaker branches appear as lateral branches." When the strong branch is developed *alternately* to the *right* and *left* side, the sympodial system is known as *Scorpioid*; but when it is constantly produced *either* to the left or to the right, the mode of branching is described as *Helicoid.* (Figs. 17 and 18).

CELL BRANCHING.

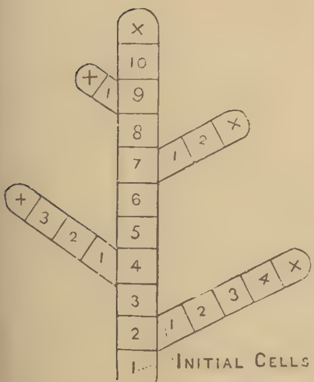

FIG. 19.—Monopodial (Racemose) branching. Acropetal growth. *Example*, most stems.

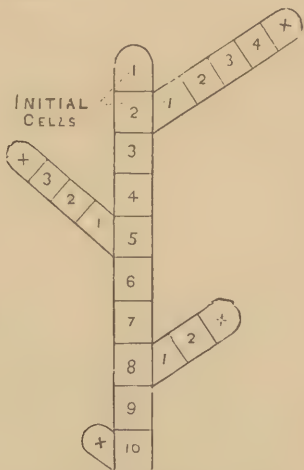

FIG. 20.—Monopodial (Racemose) branching. Basipetal growth. *Example*, leaves.

Monopodial Branching, may be either indefinite (*racemose*) or definite (*cymose*). It is the former when the axis is practically ahead of the branches, and the latter when *vice versa.*

Cymose Branching.—This is either—

a. Normal,—biparous or multiparous, or—

b. Sympodial (uniparous), when a false axis or sympodium is formed. This takes place as described already, when only one lateral axis developes vigorously in each case. As with sympodial dichotomy, here too it may either be *Helicoid* or *Scorpioid.*

CELL BRANCHING.

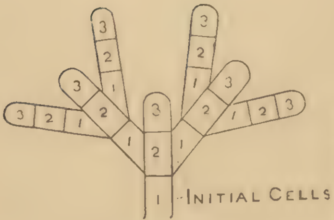

FIG. 21.—Biparous Cyme (Dichasium).

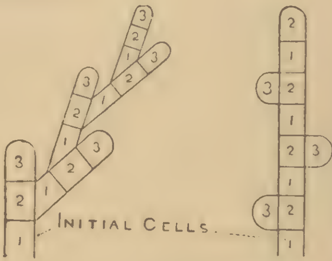

FIG. 22.—Sympodial (Scorpioid) Cyme.

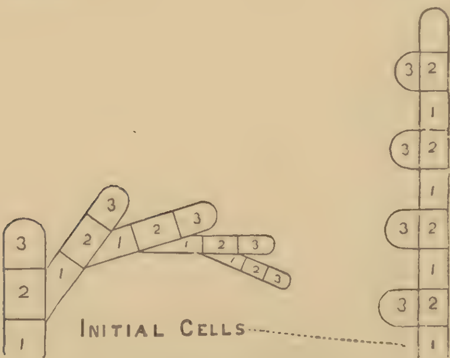

FIG. 23.—Sympodial (Helicoid) Cyme.

The order of the development of branches is either—

1. *Acropetal.*—When the youngest is nearest the apex. This is the normal and common succession.

2. *Basipetal.*—When the youngest is nearest the base.

3. *Adventitious.*—When there is no regular order of sequence.

TISSUES.

What is a Tissue?—A *true* tissue is a mass of somewhat similar cells having *common partitions*, and being at the *same phase of growth.*

False Tissue.—Is formed by the interlacing or common growing in company of cells or cell-filaments * (cell rows) originally separate.

Example—Mushroom (sporophore or above ground part), Lichens, &c.

Cœnobia † are false tissues (or colonies) formed by the gathering together of independent cells within a common envelope which is constructed by these members collectively.

Example.—Volvox.

All the tissues of a plant arise from the initial cells.

True Tissues.

The Common Cell Wall.

Is thin and delicate in the initial cells, but more or less thickened, as a rule, in permanent tissues. As it increases in thickness two parts can usually be distinguished, viz., *middle lamella*, and on each side of this the *thickening layers*. The common transverse partitions of rows of cells may break down or become absorbed completely or partially, giving rise to cell-fusions or vessels,‡ or, more

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* Usually called *hyphæ* when tissue forming.

† A cœnobium is a good example in the vegetable kingdom of co-operation for the purposes of nutrition.

‡ After a vessel has been formed one or more contiguous cells may grow into it by the protuberant expansion of the thin separating portions (middle lamella) of the pits. Such invading cells, which may ultimately divide and fill up the whole, are termed *tullen* or tyloses, and occur commonly in wood.

rarely, whole masses of cells may disappear by absorption, producing hollow stems, &c.

Through the whole body of the *permanent* tissues, except, as a rule, the vascular or skeletal bundles of the plant, numerous lacunæ or *intercellular spaces* occur. These are especially well developed in water plants.

Intercellular Spaces.

Formation.—(1) By the *splitting of the common cell wall* at the angles of junction of a number of cells, or in the middle of the partition between two cells (*Schizogenous method*).

This is a more common mode of origin than (2) by the *disorganisation* (solution, absorption, or drying up) *of cells* (*Lysigenous method*).

Example.—Hollow Stems.

Contents.—1. *Air* (hollow stems, and most of the ordinary intercellular spaces); 2. Oils (rind of orange); 3. Mucilage (Cactus); 4. Resins (Pinus); 5. Water (not common, found in certain spaces in sensitive plants, &c.); 6. Protoplasm (frequent in some cases).

Classification of Tissues.

1. Meristem or Embryonal Tissue.
2. Permanent Tissue.

Meristem.

Is a tissue composed of initial cells in different phases of growth. It passes quite gradually, by the *temporary* or *permanent* loss of power of bipartition and usual attainment of mature growth, into the permanent tissue of the plant body, to the whole of which it gives rise.

There are two kinds of Meristem:—

a. Primary Meristem.—Found at the apex of the stem: immediately behind the rootcap at the tip of the root: and intercalated between the wood and bast in *open* vascular bundles, forming *fascicular cambium.**

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* This variety of primary Meristem retains the original embryonal character of its cells, but remains dormant (as far as power of dividing goes) for a time, in this respect resembling secondary Meristem.

The cells of primary Meristem are very small, having, relatively, very large nuclei. The plumule and radicle of the embryo plant in the seed is entirely composed of

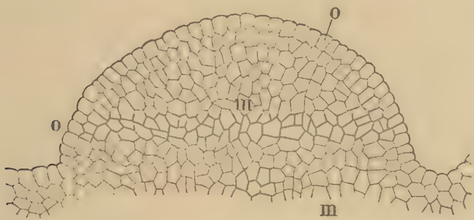

FIG. 24.—*Meristem* (*m*) from the receptacle of *Atropa belladonna.*—*o* Superficial layer; × 300 times. (After Behrens.)

this kind of tissue. The whole Meristem tissue may either originate from a *single apical initial cell*, as in the Vascular Cryptogams, or from a *group of similar initials* as in the Phanerogamia.

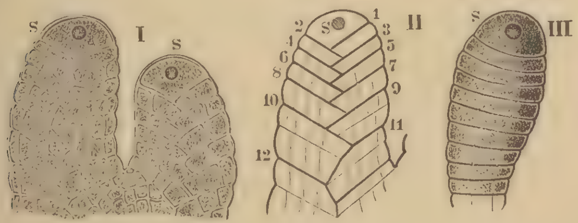

FIG. 25.—The Apical cell.—Leaves of *Marsilia uncinata.* I. Two young leaves, viewed from the front; II. Diagrammatic representation of one of the same; III. Do. from the side. *s.* Apical cell; × 600 times. (After Behrens.)

b. Secondary Meristem.—A dividing tissue produced by the *reversion* of certain cells of the permanent tissue, which have retained their active protoplasm, to the primary or *initial phase*, *e.g.*, Phellogen or cork-cambium.

The cells of meristem are normal or elongated parenchyma (*see* below).

Differentiations of Primary Apical Meristem.

At the apical portions of the axis (stem and root) the older meristem is arranged, behind the initial cells, into vertically-disposed strands of tissue, viz., *dermatogen*, which is formative of the epidermis; *plerome*, which is formative of the central portions of the axis (pith and vascular bundles); and *periblem*, which is formative of the cortex or part lying between the epidermis or skin of the young plant and the central pith and skeletal portion. In roots the dermatogen and periblem are very usually *common* or blended in one another, and in most Monocotyledons a formative layer (*calyptrogen*) cut off in front of the initial cells of the root gives rise to the pileorhiza or rootcap.

Forms of Permanent Tissue.

Parenchyma.—Cells with flat or somewhat rounded ends, thinnish cellulose walls, and very commonly with inter-cellular spaces. The parenchyma cells carry on the living functions of the plant, such as nutrition, reproduction, storing, &c. They also, however, subserve other functions of a mechanical nature, as protection, &c.

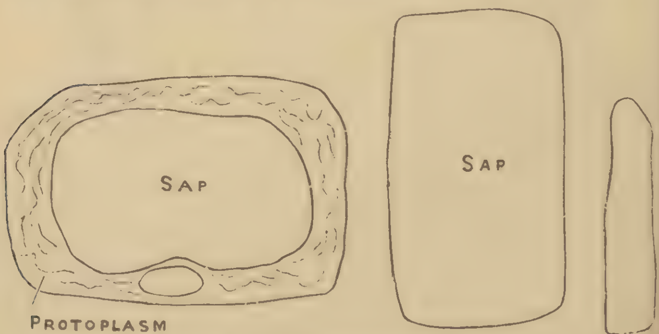

FIG. 26.—Parenchyma.

When parenchyma cells form concentrically thickened walls, and then lose their protoplasm, *i.e.*, become dead, they are termed *Sclerenchyma*. (Fig. 31).

Collenchyma.—Living parenchyma cells, thickened at the mutual corners. Function mainly mechanical.

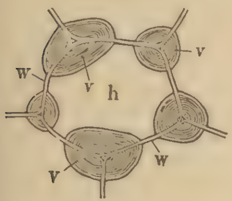

FIG. 27.—Collenchyma cell from the stem of *Richardia africana.*—*w* Unthickened cell wall; *v* Thickenings of cell wall; *h* Interior of cell.— × 600 times. (After Behrens.)

Epidermal Cells.—Superficial cells of parenchymatous shape, but having the *outer* walls transformed to cork (cuticle).

Cork Cells.—Are, when mature, dead cells of a parenchymatous form. The original cellulose wall has been changed to cork. Function protective, and to prevent evaporation of sap. All terrestrial Phanerogams are capable of forming cork, but in Cryptogams it is only found in a few isolated cases.

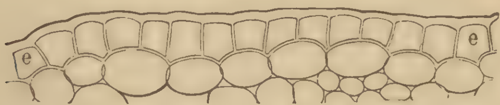

FIG. 28.—Epidermis (*e*) with cuticle. (After Behrens.)

Prosenchyma.—Greatly elongated cells with oblique or pointed ends. When mature they have thick walls and no protoplasm, and are then known as *Sclerenchyma fibres.* (Fig. 30).

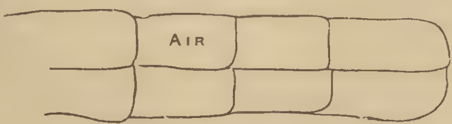

FIG. 29.—Cork Cells.

Vessels.—Rows of parenchyma with the transverse wall completely or partially absorbed. A few tubes, however, are just greatly elongated single cells. (See Latex tubes.)

Tracheæ.—The sclerenchymatous elements of the xylem

or wood part of the vascular bundles characteristically thickened. Function skeletal, and they also act as tubes for the circulation of water (sap). They are always elongated, have no protoplasm whatever, and are of two kinds :—

(*a.*) Tracheids—elongated dead cells.

(*b.*) Vasa or Vessels—rows of cells with the transverse walls absorbed. (Fig. 32).

Note.—The constituents of the vascular bundles of aquatics are not lignified.

Sieve Tubes.—Vessels formed from rows of long cells by the partial removal of the material of the transverse walls,

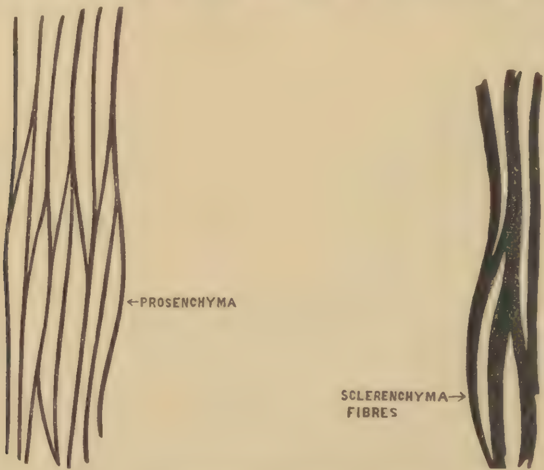

FIG. 30.—Normal and thickened prosenchyma.

making these into sieve plates. The walls are cellulose. Those tubes have always proteid contents, which they circulate mainly downwards through the plant. They are found in the bast or phloem part of the vascular bundles. (Figs. 32 and 33).

Latex Tubes.—Other vessels are found spreading and branching through the parenchyma of certain families of

plants. These are the *latex* or *milk-tubes*. They have stiffish cellulose walls and are either—

(*a.*) *Membered*—when formed in the typical way, as *cell-fusions*, by the removal of common partitions;

or

(*b.*) *Unmembered*—when formed of a *single cell* which has grown and branched through the plant without becoming septate. These are not common. They are found in Euphorbia.

FIG. 31.—Lignified cells from the endocarp (see p. 68) of an unripe walnut (*Juglans regia*); × 600 times. *i* Interior of cell, *l* Middle lamella, *w* The third layer, consisting of woody substance, *s* Inner layer, *t* Pit. (After Behrens.)

Idioblast or Secretion Reservoir.—A cell adapted for the deposition and retention of waste matters which would be poisonous and otherwise injurious to the life of the plant if allowed to remain in circulation.

The idioblasts are classified according to their contents:—

1. Crystal cells.—The crystals are usually calcium oxalate.

2. Resin cells.

3. Mucilage cells.

4. Tannin cells, &c.

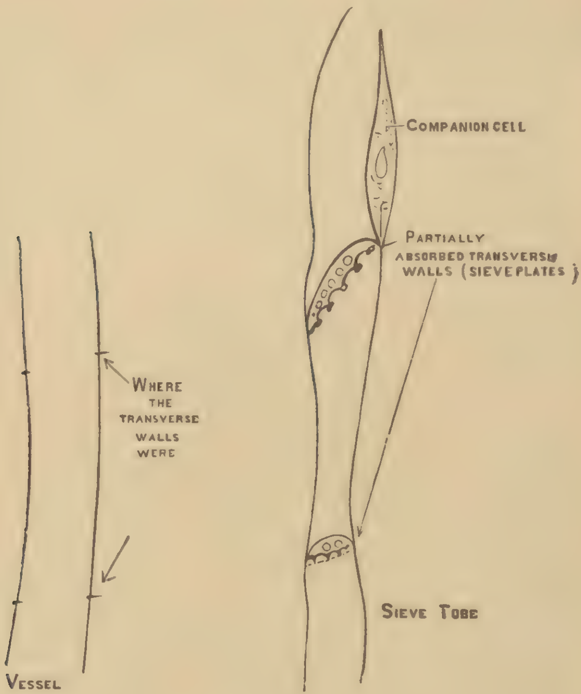
COMPANION CELL
PARTIALLY ABSORBED TRANSVERSE WALLS (SIEVE PLATES)
WHERE THE TRANSVERSE WALLS WERE
SIEVE TUBE
VESSEL

FIG 32.


SIEVEFIELD (PERFORATION IN THE LONGITUDINAL WALLS)
SIEVE PLATE

FIG. 33.

SYSTEMS OF PERMANENT TISSUES.

I. EPIDERMAL. II. VASCULAR. III. FUNDAMENTAL.

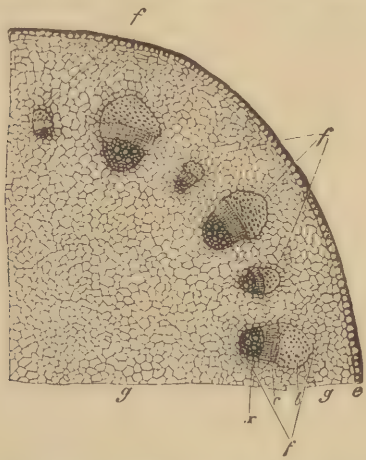

FIG. 34.—The three systems of tissue in a cross section of the petiole of Helleborus ($\times$ 20), *e*, epidermis; *g*, fundamental tissue; *f*, fibro-vascular system; *x*, xylem; *c*, bast; *b*, bast-fibres. (After Prantl.)

I. EPIDERMAL, OR LIMITARY TISSUES.

Epidermis, or First Skin of the Plant. — Developed from the dermatogen of primary meristem. Is almost invariably a single layer of cells, which in parts* of green

* Of normal plants, from the Muscineæ upwards.

plants exposed to light are of two types, viz., 1. Ordinary; 2. Stomatal Cells.

1. Ordinary Epidermal Cells:—

Shape.—Parenchymatous, are usually elongated or tubular, and have generally a wavy outline.

Cuticle.—The external wall of the whole layer is thickened with cork, forming a cuticle which has frequently embedded in it particles of wax, that cause the appearance known as "bloom."

Contents, &c.—Sometimes a little protoplasm, with big vacuoles, but very rarely with chloroplasts; more usually, when mature, full of nothing but clear or coloured sap* with or without air, or with the latter alone. The union of the *ordinary* cells of the epidermis is complete, *i.e.*, there are no intercellular spaces between them, and the function of the whole layer is protection.

2. Stomatal Cells.—Consist of *guard* cells with usually *subsidiary* neighbour and girdle *cells.* The guard cells enclose an intercellular space, formed by the splitting of the middle portion of their middle lamella, termed the *stomatic aperture.*

Occurrence.—On the epidermis of green plants *above* the surface of the ground exposed to free air and light.

Development.—A cell of the young epidermis is partitioned off from another and becomes initial. This then cuts off the *subsidiary* cells, and afterwards divides itself by a vertical wall into two cells (*guard* cells), in the common wall of which a narrow chink or *intercellular space*, formed by schizogeny, soon appears, which shortly becomes pronounced by the subsequent unequal growth of the guard cells.

The Guard Cells and Aperture.—The guard cells are kidney shaped, and their curvature is increased by light. The wall next the stomatic pore or intercellular space

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* When the sap is coloured it is almost invariably red or brown.

is peculiarly thickened. Each guard cell contains protoplasm *with abundant chloroplasts.* The position of the guard cells is usually only very slightly within or below the general surface of the epidermis, but in Pinus they are deeply depressed. When the aperture, which *externally* has a narrow elliptical or slot-like appearance, is observed as it passes *into the* plant, it is usually seen to be shaped like an hour glass—wide on the outside, narrow half way through, and wide again at the inner end. Its size is increased during the day-time by the irritant action of light on the guard cells.

The above description applies to the common or *Air Stomata*, which have the function of admitting air to, and allowing gases to escape from, the plant, but there is another class of stomata :—The Water Stomata.

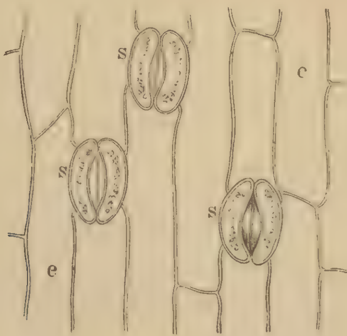

FIG. 35.—*Stomata.*—Portion of epidermis from the under side of the leaf of *Leucojum vernum*, × 300 times. *e* Epidermic cells; *s* Guard cells. (After Behrens.)

The Water Stoma, in structure, resembles the air stoma, but has a wider aperture, which does not close under the influence of light, as its guard cells are not curved by that irritant, owing to their having sufficiently rigid walls. Its function is to allow the emission of fluid, and it has the same distribution on the plant as the air stoma, but is not so common. Many of the "dew"-drops which we find on

leaves in the early morning have come into their situation through the water stomata, which they generally cover.

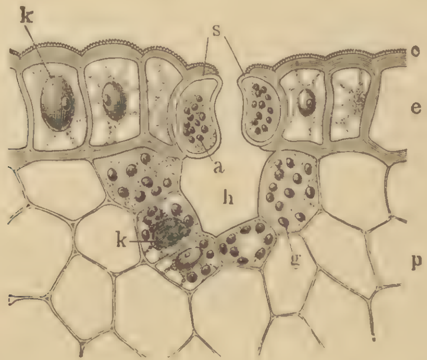

FIG. 36.—*Stomata.*—Stomata in a transverse section of the ovary of *Agapanthus umbellatus*, × 600 times. *s* The two guard-cells, containing protoplasm and starch granules (*a*); below, the air space (*h*), here bordered by five parenchyma cells (*p*), all containing chlorophyll corpuscles (*g*), and two of them with a nucleus; *e* Epidermic cells; *k* Large nuclei of do.; *c* Corrugated cuticle. (After Behrens.)

Trichomes or Hairs.

Are products of the epidermis. They are of two kinds :—

(*a*.) True Hairs.—Products of *single* epidermal cells.

(*b*.) Emergences.—Products of an initial cell *below* epidermis, and also of the epidermal cells surrounding this.

Example.—Prickles of Rose.

Development of Hair.—The true hair begins from one initial epidermal cell. This cell grows and protrudes outwards, the part within the epidermal surface developing into the *foot*, and the protruded portion into the body of the hair. Divisions may or may not accompany growth. *Development of an emergence* begins by the local growth in like manner of a sub-epidermal initial cell, and of the epidermal cells immediately surrounding this; divisions always accompanying growth.

Periderm or Cork.

Cork always originates in the epidermis or living parenchymatous cells (usually in the cortex). When it entirely takes the place of the epidermis (which occurs in very many plants after the first or second year of their existence) it is known as *periderm*. This tissue of cork cells with complete union (*i.e.*, without intercellular spaces), is usually produced as follows :—

A single layer of cells in the cortex* becomes initial (secondary meristem), and cuts off, parallel to the surface (more or less), successive layers of cells, which form practi-

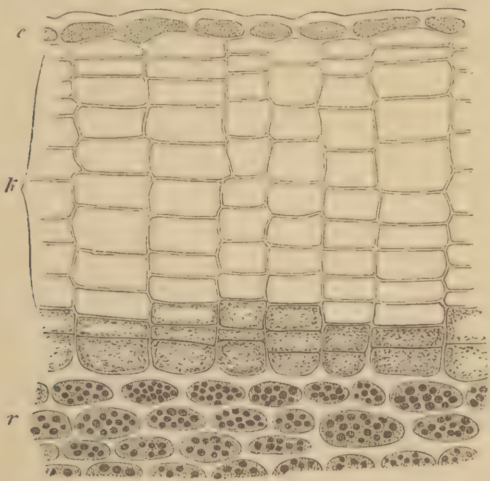

FIG. 37.—Cork of one year's shoot of *Ailanthus glandulosa* (trans. sect. × 350); *e*, the dead epidermis; *k*, cork cells, the inner layers meristematic (phellogen); *r*, primary cortex. (After Prantl.)

cally complete corky walls, and then lose their contents. The layer of initial cells is known as *phellogen*, or cork cambium, the cork cells collectively constitute the *periderm*,

* In the willow the epidermis itself becomes the phellogen, and in the poplar the layer immediately below this. In the vine and some others the cork cambium originates in the bast or phloem.

and the normal cortex chlorophyll containing cells (if any) within the phellogen, the *phelloderma*.

Bark.—Usually we have in perennial plants, particularly in trees and shrubs, *successive phellogens*, which form one within the other as the previously acting layers become exhausted. In this way the phellogen ultimately retires to the base of the cortex, and then finally into the bast of the vascular bundle, where it remains, cutting off the characteristic rings or scales known as *bark*.

Lenticels.—Peculiar small masses of tissue of cork cells, produced from the phellogen, with intercellular spaces which usually originate in stems of trees and shrubs below the stomata, and finally take the place and function of these structures after the epidermis is exhausted or gone.

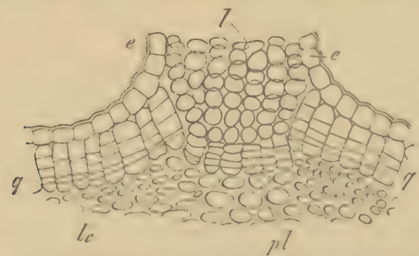

FIG. 38.—Lenticel in the transverse section of a twig of Elder (× 300); *e*, epidermis; *q*, phellogen; *l*, cells, and *pl* the phellogen of the lenticel; *lc*, cortical parenchyma containing chlorophyll. (After Prantl.)

II. Vascular Tissue.

The ground or fundamental tissue of the higher plants is traversed by strands or bundles of elongated and variously modified cells and vessels, which are specially connected with the circulation of fluids (water and organic food stuffs), and in part with a skeletal function. They are typically composed of *tracheæ* (the wood or *xylem* part) and *sieve tubes* or elements (the bast or *phloem* part), with some parenchyma. The xylem and phloem of the bundle may be *collateral*, *i.e.*, side by side, the phloem being *external* to the xylem, as in Dicotyledons and Gymnosperms generally, or

bicollateral (not common) when there are *two* bast portions, *one external* to, and the *other internal to*, the xylem, *e.g.*, Cucumber; or *concentric* when the bast part *completely surrounds* the xylem, as in ferns and lycopods; or the xylem and phloem parts may *alternate* with each other, giving rise to what is termed the *radial* arrangement, as the primary bundles of roots.

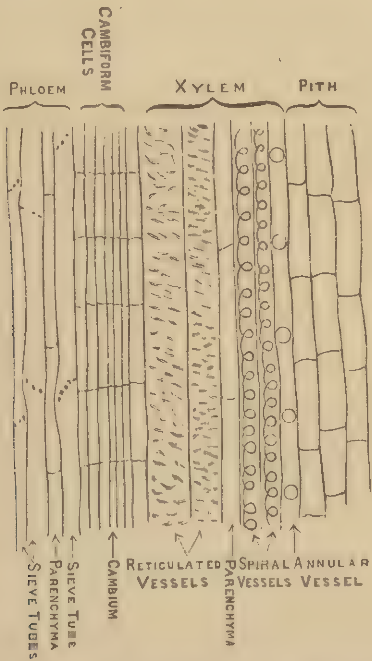

FIG. 39.—Simple Open Vascular Bundle from young shoot of Sunflower, × about 300 times.

Open and Closed Bundles.—When a meristem (*fascicular cambium*) exists between the xylem and phloem, the bundle is said to be *open*, and closed when there is *no* intercalary meristem. The open bundle may be collateral, bicollateral, or radial, *but never* concentric. Any of these types men-

tioned, however, may be closed. Open bundles are only found in the roots and stems of Dicotyledons and Gymnosperms.

Development of a Vascular Bundle.

1. At first it is part of the primary meristem of the plant.

2. By greater elongation of its cells as it passes behind into permanent tissue it becomes distinct from surrounding cells. This elongated group of strands of similar cells is known as *procambium*.

3. The procambium cells next become differentiated into sieve and tracheal elements *completely* or *incompletely*. If the former, a closed bundle is constituted, as in monocotyledons and Vascular Cryptogams, but if a layer of the central part of the procambium bundle retains its original meristem or initial character, then an open bundle results, which can be increased by *continued* divisions in this meristem or *fascicular cambium*.

A procambium group frequently gives rise to a third part of permanent tissue outside the sieve tube or true bast portion, but forming with it and the xylem one common bundle, which in this instance is called a fibro-vascular bundle, to distinguish it from the more typical case. This third portion is known as hard bast, because it is entirely formed of *sclerenchyma fibres* or *stereids*.*

Protoxylem and Protophloem are the first formed parts of the xylem and phloem respectively in the procambium bundle.

Primary Xylem and Phloem.—The xylem and phloem made from the procambium bundle.

Arrangement of the Vascular Bundles.

In the stem—

1. *Zonal*, or form a ring. In this case they run straight up and down the stem.

Example.—Dicotyledons and Gymnosperms.

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* These stereid groups commonly stand quite apart from the vascular bundles in the parenchyma of the ground tissue, but they very frequently conjoin with these, as noted in the text, forming partial or entire sheaths round them, or at least yielding a massive support.

2. *Scattered.*—In this case they run curved.

Example.—Monocotyledons.

3. *Zonal Cylindrical Net.* Here they form a row near periphery, and anastomose or branch into one another as they pass up and down through the stem.

Example.—Stem of Aspidium.

4. *Axile.*—When bundle or bundles occupy centre of axis.

Example.—Typical roots.

The bundles of the root are coalescent and continuous with those in the stem. Vascular bundles are said to be *cauline* when they do not bend out into the leaf: *common* when they bend out to and terminate in the leaf. *Leaf-trace* is the name given to that portion of the common bundle in the stem.

Termination of the Bundles in Stems and Roots.

They pass up or down, as the case may be, into the procambium strands, and through these to the initial cells of the primary meristem at the apices. The bundles which pass into the leaves on the other hand terminate in the permanent tissue (originally meristem) of those organs. The xylem part of the bundle is the most persistent in the leaf. It either ends in contact with the green manufacturing parenchyma, or in a cap of water conveying parenchyma, which lead to the water stomata.

Venation = Arrangement of the Veins or vascular bundles in the leaf.

1. *Reticulated.* —When small bundles or veins proceeding from the larger branch and anastomose greatly.

Example.—Dicotyledons.

2. *Parallel.*—When the visible and more prominent veins run straight (or gently curved without conspicuous branching) from base to apex of leaf, or from a midrib to the margins of that structure.

Example.—Monocotyledons.

3. *Forked or Bifurcate.*—When the ends of all the veins or bundles branch dichotomously.

Example.—British Ferns.

4. *Centric.*—When the bundles are axile, as in Pinus leaf, or zonal, as in tubular leaves (Onion).

III.—Fundamental or Ground Tissue.

Definition.—All the mass of tissue except the epidermal and vascular systems.

Constitution.—The ground tissue is chiefly composed, as a rule, of parenchyma with thin walls. When the vascular bundles of the stem have a zonal arrangement, as in Dicotyledons, the ground tissue is roughly separated by them into two parts *Pith*, internal to, and *Cortex*, external to, the bundles, and in this case the portions of the ground tissue which connect the pith and cortex between the vascular bundles are known as *primary medullary rays* (compare with *secondary* medullary rays below).

Modifications of Ground Tissue.

1. *Hypodermis.*—The parenchyma immediately beneath the epidermis is frequently different from the rest, owing to its having assumed skeletal or mechanical functions. This modified parenchyma is called hypodermis. It occurs either as a layer lining the epidermis, or in more or less isolated groups. The *collenchyma* already noticed (see page 37) is an important variety of hypodermis.

2. *Endodermis*, or Bundle Sheath.—The modified portion of the ground tissue in contact with the vascular bundles. It is very common, though not always developed or distinguishable. It generally forms a purely protective band, but may, as in many Dicotyledons, constitute an almost ordinary parenchymatous layer, utilised as a store of starch.

3. *Mesophyll.*—This is the ground tissue of leaves. In green or foliage leaves it is usually differentiated to a greater or less extent (according to whether the plant stands higher or lower in the scale of being) into *palisade cells* and *spongy parenchyma*, the former being rather elongated and closely set cells, with minute intercellular spaces, and the latter broad or very irregularly shaped, with large inter-

cellular spaces. In bifacial leaves the palisade arrangement is towards the upper surface; in centric or tubular leaves it is all round. The most perfect differentiation of mesophyll occurs in Dicotyledons, then in Gymnosperms. It is imperfect in the Monocotyledons and lower plants, and in many cases scarcely at all existent. (See page 71).

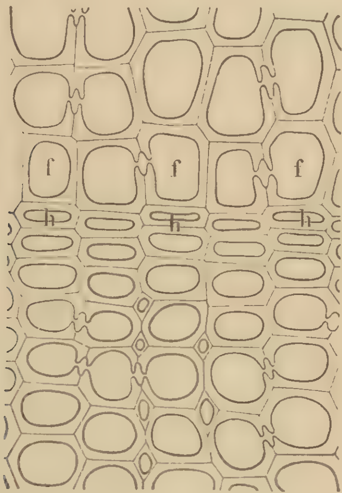

FIG. 40.—Formation of the annual ring in a three-year-old pine trunk (*Pinus sylvestris*).—*f f* Wood-cells formed in spring; *h h* The same formed in autumn; × 600 times. (After Behrens.)

GROWTH IN THICKNESS.

Typical stems and roots increase in thickness by the formation of meristem rings which are—1. *Cambium*; 2. *Special Meristem*; or 3. *Phellogen.** We have already considered the latter (see p. 45), which does not, however, do very much of the thickening. The first named is found only in Dicotyledons and Gymnosperms.

* Or phellogen plates in scaly barks.

Formation of Cambium Ring.

1. In Stems with open Collateral Vascular Bundles. The *primary meristem* or *fascicular* cambium between the primary xylem and phloem of the bundles begins to divide, and *infects* with the same dividing property a layer of the living and hitherto permanent cells of the primary medullary rays lying between the fascicular cambium of the bundles. These new bridging layers of *secondary* meristem are now known as *interfascicular cambium*, and the two cambiums thus constituted together form a complete *cambium ring*. By the practically simultaneous division of the cambium ring cells all round, new wood is formed to the inside in the growing season—and thus we get our yearly rings in trees—and new bast to the outside. The new wood and bast made by the cambium ring are termed respectively *secondary xylem and phloem*, to distinguish them from the primary wood and bast which are transformed procambium cells. The cambium ring cells lying next to the primary medullary rays continue these, and also form *secondary medullary* rays which are elliptically shaped, transversely running parenchymatous cell groups, ending blindly in the xylem and phloem.

2. *In Roots* of Dicotyledons and Gymnosperms, a cambium ring forms in much the same manner, but as the primary phloem and xylem alternate in this case, the ring is at first a sinuous or curved one; by unequal divisions or growth, however, it soon becomes quite round.

According to the *number* of primary vascular bundles which it contains, the root is *Diarchal*, *Triarchal*, or *Polyarchal*.

Other stems and roots than those belonging to Dicotyledons and Gymnosperms only exceptionally increase regularly in circumference after their cells have reached the mature or permanent phase, and when increase does regularly occur it is by the

Formation of a Special Meristem Ring,

not cambium, because the vascular bundles in the cases referred to are *closed*. The stems and roots of the tree

Liliaceæ of the Monocotyledons increase in thickness by the formation of a special meristem ring *in the cortical* (cortex) *region* of the ground tissue outside of the primary vascular bundles. This secondary meristem ring develops new closed vascular bundles and new ground tissue.

Secondary thickening very rarely occurs in plants lower than Phanerogams, but when it does take place, as in the thallus or unmembered(?) plant body of Laminaria (tangle), &c., it is produced by the formation of a special meristem in or near the peripheral part.

Secondary thickening occurs in the higher plants in the carpels or accessory parts, or both, during the formation of many fruits.

Secondary Wood and Bast.

The Secondary Xylem is composed of :—

1. *Tracheal part* (but no vessels or vasa in secondary xylem of Gymnosperms).
2. *Skeletal part* (purely).—Sclerenchyma fibre.
3. *Medullary rays.*—Parenchyma.

The Secondary Phloem is composed of—1. *Sieve tubes* and parenchyma ; and 2 and 3 as above under Xylem.

EXTERNAL MORPHOLOGY OR ORGANOGRAPHY.

The mature plant body, which is constructed of cells and tissues, is differentiated into members that were all primarily made in the same manner out of meristem, but have become changed in various aspects in order to properly divide and share the physiological labours of the organism.

In the higher plants we recognise three great sets of members:—

1. *Roots;* 2. *Stems;* 3. *Leaves.*

In the lowest plants (Thallophyta), where there is no differentiation into root, stem, and leaf that can be in the least degree *anatomically* compared with those parts of the higher plants, we speak of the general vegetative body as a—

Thallus.—A member having typically an irregular undefined form, it may be unicellular or a multicellular cell-filament, or a cell-surface or cell-mass, and it may be simple and delicate or complex in structure, and, in some of the higher or debateable organisms of the Class Thallophyta, strikingly like the roots and shoots of higher plants, at least in general appearance.

Mycelium.—Is the name given to the branching thallus or vegetative hyphæ of Fungi, spreading in or on the substratum.

The *Sclerotium* is a resting condition of mycelium. It is a tuber-like multicellular body filled with nutrient material which, when mature, becomes detached from the mycelium producing it, and, after remaining dormant for a time, puts out shoots that develop into "fructification." In Myxomycetes the sclerotium is developed out of a plasmodium (naked multinucleated protoplasm).

Protonema.—Is a pluricellular filamentous or plate-like form of thallus? found in Muscineæ, upon which the conspicuous plant, bearing sexual organs, is developed as a lateral or a terminal shoot.

The Root-System.

The typical root is only found in vascular plants. In the lower vegetables the parts having the same functions are termed rhizoids, &c. The uses of roots are twofold :—

1. Fixing ; 2. Absorbing.

The Typical Root.

Characters.—(1.) Has a root cap. (2.) Has a central vascular cylinder. (3.) Produces rootlets endogenously. (4.) Has an ill-defined epidermis which, in its younger parts, produces tubular outgrowths or root hairs. (5.) *Never bears leaves.*

Structure and Development.—See under each plant-type considered.

Branching.—Almost invariably occurs in an acropetal manner, by the successive productions of endogenously developed lateral branches.*

Functions.—To fix the plant in the soil and absorb water with mineral matters, in solution, through the root hairs.† The fixing is mainly accomplished by the mature or older roots shortening themselves by the contraction of their parenchymatous cortex and axial cylinder. The absorbing function is only performed by the *young roots* through the epidermal hairs with which their surface, beginning some little distance back from the growing point, is invested.

Root Systems.

There are two great kinds—1. Tap ; 2. Adventitious.

Tap Root.—The first main or axial root, formed as a continuation of the primary stem, is produced more or less in all cases, but only develops and persists in Dicotyledons

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* Very rarely branching takes place by the dichotomous division of the growing point behind root cap.

† Those minerals are either naturally soluble in water or brought into a state of solution by means of the acid excretions of the root hairs.

and Gymnosperms. In the other cases it remains inconspicuous as an almost invariable rule, or dies down after considerable development. (*See* development of this primary root under Helianthus and Aspidium.)

A Tap Root System is a system in which the tap root persists and forms the parent of all the other roots of the plant.

*Adventitious Root.**—Any root developed from a stem (or leaf).

In the *Adventitious Root System* all the roots of the plants arise from the stem.† This system is found in, and is characteristic of, all the vascular families of plants other than the Dicotyledons and Gymnosperms.

Secondary Roots.—All roots other than tap roots are called secondary.

Metamorphosed Roots.

1. Storing roots, *e.g.*, turnip.
2. Lignified older roots of trees.
3. Aerial roots, *e.g.*, ivy, epiphytic orchids.
4. Aquatic roots.
5. Parasitic and saprophytic roots, the most metamorphosed, or rather degenerated, of any.

Rhizoids.—The simple structures of mosses, algæ, and lichens, which merely agree with true roots in certain of their physiological functions.

Rhizophores.—Portions of aerial shoots which assume the form and functions of ordinary roots on penetrating the soil, *e.g.*, Selaginella.

The Stem System.

Definition of a Stem.—Any part of a plant that bears leaves. The typical stem differs from the typical root in having its growing point naked, *i.e.*, is without anything corresponding to the root cap, although its apex is normally protected by overlapping young leaves which, together with it, constitute a bud.

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* This term has another application, see Glossary.

† Or, very rarely, the leaves.

The Typical Stem.

Form.—More or less cylindrical as a rule, but may be triangular, square, &c.

Position.—Erect (usual) or oblique.

Regions.—1. Hypocotyledonary—the portion of the primary stem below the cotyledons or seed leaves. 2. Scale leaf region—the part which normally develops above 1. 3. Foliage leaf region—part above 2 which produces the green manufacturing leaves. 4. Bract leaf region—from which the flowers spring. 5. Floral or flower region. Only in the primary stem can all these regions be developed. In secondary stems or branches we may get all from 2 or 3 or 4, according to the part of the parent axis from which they originated, but none of the regions under those.

Nodes.—The portions of the stem from which the leaves are produced. The stem always branches at the nodes.

Internodes.—The parts between the nodes.

Structure and Development of the Stem.—(*See* under each plant type, considered further on.)

Branching.—Is of two kinds—

1. Monopodial (common).
2. Dichotomous (rare).

Monopodial Branching.—When the axis produces lateral branches in acropetal order, and forms a single common axis for all the branches. There are three kinds—

(*a.*) *Racemose* (ordinary kind), *e.g.*, elm.

(*b.*) *Cymose.*—When at an early stage the growth of each lateral axis becomes more vigorous than that of the primary axis above the place of origin of the former. There are two varieties—

(1.) False Dichotomy (Dichasium) or False Polyotomy. —No false axis appears in this case, because the two or more sets of lateral branches which are developed in different directions grow with nearly equal vigour. This form of branching is also known as biparous (or polyparous) cyme, and is found in the vegetative shoot of the mistletoe, and in the inflorescence of the Caryophyllaceæ (Pink Family). (See Figs. 21 and 46).

(2.) Sympodial Cyme or Uniparous Cyme.—When a false general axis is formed by the one lateral branch produced developing more vigorously than the apical portion of its parent, and then giving rise near its own summit in like manner to a lateral branch which develops more vigorously than itself, and so on. There are two varieties —Helicoid Cyme and Scorpioid Cyme (see page 32).

Dichotomous Branching (see page 31).

Characters of Typical Stem.—1. Has a naked growing apex (with nothing corresponding to root cap). 2. Has in most cases a more or less zonal arrangement of vascular bundles or skeletal tissue. 3. Branches exogenously (unless when producing adventitious members). 4. Has when young a well-defined epidermis. 5. *Bears leaves.*

Functions.—Exposes its assimilating organs (leaves) properly to the light and air, and acts as a channel through which materials are conveyed from roots to leaves and *vice versa*.

Metamorphosed Stems.

1. Runner.—A stem which creeps along the surface of the ground, producing at its nodes leaves from its upper and roots from its under surface.

2. Storing *under ground* stems—
   (*a.*) Rhizome—elongated, *e.g.*, Fern.
   (*b.*) Corm—short erect, *e.g.*, Crocus.
   (*c.*) Tuber—short fleshy branch, *e.g.*, Potato.

3. Storing *above ground* stems, *e.g.*, Cactus.

4. Twining stem.—A weak main stem which twines about from left to right or right to left, *e.g.*, Convolvulus.

5. Stem tendrils.—*Secondary* stems or branches modified to act as climbers and supporters of the main stem, *e.g.*, Vine.

6. Spines.—When the apices of stems modify into permanent hard thorns, *e.g.*, Hawthorn.

7. Cladode.—A leaf-like or flattened stem modified to perform the functions of a foliage leaf, *e.g.*, Ruscus.

8. Frondose stem.—When the whole shoot is reduced to a simple leaf-like expansion.

Example.—Lemna (duckweed).

Bulb.

A fleshy (and usually subterranean) bud which has departed from its normal function and become a storehouse of nutriment, There are two kinds of bulbs—

1. *Scaly.*—When the overlapping fleshy leaves are not cylindrical, but imbricated.

Example.—Lily.

2. *Tunicated.*—When the leaves are cylindrical, going completely round the bulb.

Example.—Onion.

The Leaf.

Definition and Characters.—The lateral expansion of a stem. It always originates *exogenously* and in *acropetal* succession, and assumes a shape different from that of the stem upon which it is borne. Leaves are usually limited, but they may be (especially in the lower plants) indefinite in their growth.

Parts of Typical Leaf.—

1. Blade or lamina.
2. Stalk or petiole.—When this is absent the leaf is *sessile.*
3. Sheath.—At base of leaf; may be poorly or well developed; complete, or very limited and ill defined.
4. Stipules.—Appendages at the base of a leaf. Often absent. They are usually considered as belonging to the sheath.

Phyllotaxis, or Arrangement of Leaves on the Stem.

Alternate (usual case).—When only one leaf is given off at each node.

Opposite.—When two leaves are given off at each node. Paired or opposite leaves are almost always decussate, *i.e.*, contiguous pairs stand at right angles to each other.

Whorled.—When more than two leaves are given off at each node.

Spiral Arrangement of Alternate Leaves :—

1. Distichous or *one-half* arrangement. When drawing a spiral line from any leaf to the next one further up the stem we have to go round half the circumference of the stem.

Example.—Grasses.

2. Tristichous, or one-third arrangement. When the spiral line in going round the stem once from leaf-base to leaf-base in due order passes three leaves on its way. This is the common arrangement in *Monocotyledons.*

3. Pentastichous or two-fifth arrangement. When the spiral line in going *twice* round the stem passes *five* leaves on its way. This is the common arrangement in *Dicotyledons.*

Types of Leaves.

1. *Bifacial* (*common*) ; 2. *Centric.*

Bifacial Leaf.—Flattened blade with upper and under surfaces clearly distinct. Internally, also, the tissues show a general special differentiation towards the different faces (see page 50).

Centric Leaf.—The blade, which is more or less cylindrical, has no, or but very slightly, marked distinction of upper and under surfaces, and, internally, the tissues are in general arranged right round the leaf interior, or centrically (see under Pinus).

Structure and Development of the Leaf.—(See under each plant type).

Branching of Leaf.—As in stems :—

1. Monopodial (Racemose and Cymose).
2. Dichotomous (rare).

Venation.—*Reticulated*, in Dicotyledons generally. *Parallel* or straight in Monocotyledons generally, and *forked* in British Ferns (see page 49).

Classification.

The classification of leaves depends mainly on the nature of their blades. Leaves are either *simple* or *compound*, and each of these, again, are either *Pinnate* or *Palmate*. A simple leaf is one not naturally cut or divided up *right into its midrib* or principal vein; a compound leaf is so divided.

A palmate leaf is one which has a blade *at least* about *as broad as long;* such a leaf has a short midrib, a mere point, at the base of the blade, from which all the other veins arise. The blade of a pinnate leaf is longer than broad, and its midrib is long, *i.e.*, runs from the base right up towards the apex of the blade.

Entire Leaf.—When the blade is not cut into at all.

Toothed Leaf.—When the marginal part is indented.

Pinnatifid Leaf.—When the cutting of a simple pinnate leaf extends from about a third to half-way into the midrib.

Pinnatisect Leaf—When the cutting of the *pinnate* blade goes at least half-way into the midrib.

Pinnatipartite Leaf.—When the cutting of the *pinnate* leaf is *almost* right into the midrib.

Palmatifid—sect—partite Leaves—As above, but the blade, which is cut into, is *palmate.*

Functions of Typical Leaf.

Foliage Leaf:—

1. *Transpiration.*—Its broad thin surface makes it a very efficient organ for the evaporation of water from the plant.

2. *Assimilation* (*Elaboration*).—The carbohydrates (and possibly other organic compounds) required by the plant for nutrition are manufactured in the leaf blade.

3. *Respiration.*—The leaf is a great organ of respiration in the plant.

Special Forms of Leaves.

1. *Cotyledons*—The first or seed leaves. They are of short duration.* Are present in all embryos of ordinary vascular plants.

(*a.*) *Kinds and Functions.*—1. *Hypogeal* cotyledons, which remain below ground, and are either *storehouses* of food stuffs when the seed is *exalbuminous* or *suckers and conveyers* of nutriment from the endosperm, for the young shoot and root (plumule and radicle) when the seed is *albuminous* (see page 76). 2. *Epigeal* cotyledons, which latterly come above ground, and, developing chlorophyll, form the first foliage, or assimilating leaves of the plant.

Examples of 2.—Pinus, Maple.

The usual primitive function of the epigeal cotyledon is to act as a *sucker and conveyer of nutriment* from the endosperm to the growing axis of the embryo of the seed; it rarely acts as a storehouse itself.

(*b.*) *Number.*—Usually two in Dicotyledons; one in Monocotyledons; two or more in Gymnosperms; one, two, or more in the Vascular Cryptogams.

2. *Scale Leaves* (Cataphylls).

(*a.*) *Characters.*—Yellow or brown and dry and scaly (usually), or white or yellow and fleshy, of simple structure without projecting veins, and attached to the stem by a broad base.

(*b.*) *Occurrence.*—On subterranean stems, on the outside of buds,† or, more rarely, as in parasites, distributed from the base of the stem up to the floral organs.

(*c.*) *Functions.*—1. Protective (usual): 2. Storehouses of food when fleshy.

3. *Foliage Leaves, Special Forms of*, or Metamorphosed.

(*a.*) *Dissected.*—Submerged leaves of aquatics.

Example.—Water Ranunculus.

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* Cotyledons are permanent, however, in Welwitschia and Streptocarpus.

† They usually fall off as the bud develops. The following native trees produce buds without the usual investing scales:—*Viburnum Lantana*, *Rhamnus Frangula*.

(*b.*) *Lattice and Split Leaves.*—Due, the former to drying and tearing of isolated portions, and the latter to the splitting of an originally entire blade.

(*c.*) *Peltate.*—When the blade is attached to its petiole (or point of insertion), not at its basal margin, but at some part *within* the margin.

Example.—Indian Cress.

(*d.*) *Tubular*, *e.g.*, Onion.

(*e.*) *Phyllode.*—Flattened petiole which takes on the normal function of the blade.

Example.—Acacia (some species only).

(*f.*) *Ascidium.*—A name applied to the blade of a leaf when metamorphosed into a pitcher which acts as an organ for securing insects, etc., for the purpose of food.

Example.—Nepenthes.

(*g.*) *Leaf Tendril.*—Any part of a leaf may be changed into a tendril or slender sensitive thread or cord-like process, adapted for catching hold of, and twisting round a support. Petiole-tendril, *e.g.*, Tropæolum (Indian Cress). Blade-tendril, *e.g.*, Lathyrus aphaca, where the *whole* blade is changed into a tendril, and the Pea, where the upper portion is only so changed. Stipule-tendril, *e.g.*, Cucumber.

(*h.*) *Leaf thorn.*—For defence or protection.

Petiole-thorn—When the blade separates off from the stalk the latter may be converted into a thorn, *e.g.*, Astragalus.

Blade-thorn—When the blade or entire leaf is changed into a thorn, *e.g.*, Furze (Whin) Barberry.

Stipule-thorns, *e.g.*, Robinia pseudacacia.

(*i.*) *Bract.*—A more or less modified, and usually, foliage leaf, from the axil of which a flower, or stalk bearing flower or flowers, springs. They are sessile, with a narrow base of insertion, very commonly green, but sometimes coloured. A *Spathe* is a large bract enclosing a young inflorescence. An *Involucre* is a *whorl* of bracts.

The glumes of grasses are bracts.

4. *Sporophyll.*—A leaf which bears sporangia. This may be an ordinary foliage leaf, as in Aspidium, or a specialised floral leaf, as in Phanerogams. The essential parts (stamens and carpels) of the flowers of the latter are sporophylls, and these are generally enveloped by one or more whorls of the non-essential floral leaves (calyx and corolla), or by bracts.

THE TYPICAL FLOWER.

Parts.—Essential or sporophylls (carpels and stamens), non-essential or envelopes (corolla and calyx). These parts are usually in whorls one within the other. A flower is *complete* when all these parts are present, *diclinous* or *unisexual* when only one kind of sporophylls (carpels or stamens) are present, *hermaphrodite* when both are present. *Monœcious* flowers are unisexual flowers occurring on a plant producing *both* male (staminate) and female (pistilate or carpel-bearing) flowers, but when the sexes occur on *different* plants the flowers are *diœcious*: *dichlamydeous*, when both whorls of floral envelopes are present (calyx and corolla); *monochlamydeous*, when only one; and *achlamydeous* when none of these are present. In the latter case bracts or some other special covering may perform the function of the floral envelopes, or the flower may be quite naked. The flower is *regular* when each part of the floral envelope, or most prominent floral envelope, if there be two distinct whorls, is equally developed.

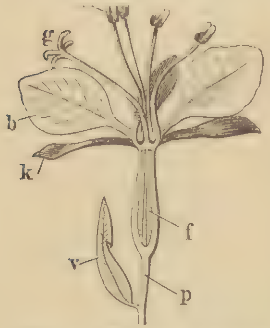

FIG. 41.—Epigynous corolla. Willow-herb (*Epilobium angustifolium*) longitudinal section; nat. size. (After Behrens.)

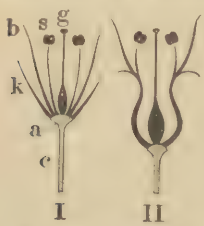

FIG. 42.—I. Hypogynous; II. Perigynous. (After Behrens.)

The flower is a shoot, and therefore consists of—1. a stem part, the *Torus* or *Receptacle*, which is the top of the flower-stalk or peduncle, if this be present; and 2. *the leaf part*—the floral leaves. It is,—according to the position of its female sporophylls, which are usually united together to form *one ovary*—*hypogynous* when the other parts of the flower are inserted beneath this, *epigynous* when above. *Perigynous* is a modification of hypogynous in which the torus is hollowed.

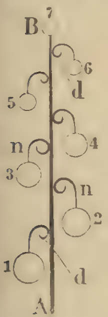

FIG. 43.—Raceme.

INFLORESCENCE.

Definition.—The arrangement of the flowers on the plant. The portion of the stem bearing the flowers is the *Axis of Inflorescence.*

Classes of Inflorescence:—

1. *Indefinite.*—When the terminal bud is a foliage leaf or mixed bud, the main axis being more or less indefinite in its growth. In indefinite inflorescences the *lowest* or *outer* flowers expand first. When the *axis* is *long* and the *flowers* are *stalked*, the inflorescence is a *Raceme*, and

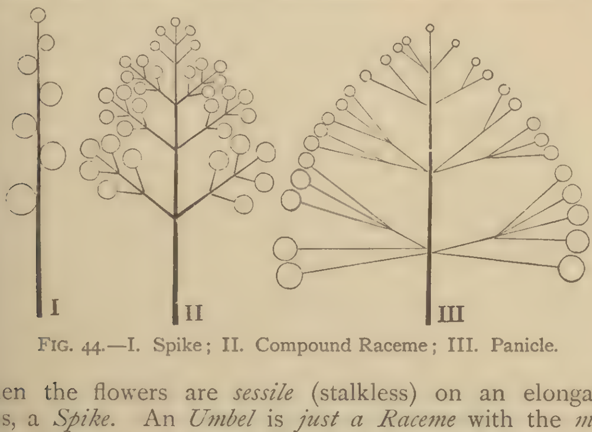

FIG. 44.—I. Spike; II. Compound Raceme; III. Panicle.

when the flowers are *sessile* (stalkless) on an elongated axis, a *Spike.* An *Umbel* is *just a Raceme* with the *main axis so contracted* that the stalked flowers appear all to

spring from the same level, and a *Capitulum* is a similarly contracted spike, only in this case, as the flowers are sessile, the contracted axis has to be broadened out, slightly conical or rounded, and more bulky.

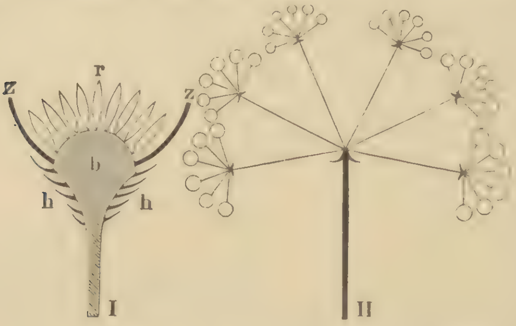

FIG. 45.—I. Capitulum; *b*, axis; *h*, bracts; *z*, *r*, flowers. II. Compound Umbel. (After Behrens.)

2. *Definite.*—When the terminal bud is a flower bud (or flower), the main axis being thus perfectly definite in its growth. In definite inflorescences *the apical or*

FIG. 46.—Dichotomous or Biparous cyme. (After Behrens.)

central flowers expand first. When some distance below the flower-ending main axis, *two* (or rarely more) equally developed lateral axes are given off, each of which also

terminates in a flower or flower-bud, the inflorescence is a *Biparous Cyme.* (We have a contracted form of this in the Labiatæ or Deadnettle family.) When the cyme is uniparous or of the sympodial type, forming a false

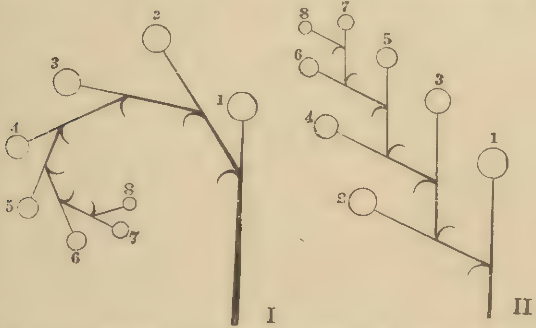

FIG. 47.—I. Scorpioid cyme; II. Helicoid cyme. (After Behrens.)

axis, it is either Helicoid or Scorpioid (*see* page 32). There are compound and mixed forms of all these inflorescences, indefinite and definite.

THE FRUIT.

Definition.—The mature ovary.

Parts.—The mature ovary wall (*pericarp*), and mature ovule or ovules (*seeds*).

Classification.—Fruits are grouped according to the nature and behaviour of their pericarps.

Etærio.—Collection of achenes or drupes upon a single receptacle which is typically convex: when hollow it is a Cynarrhodum (rose). The receptacle may be succulent or not.

Aggregate Fruits:—

1. *Syconus*—Collection of achenes upon the inner surface of a cup-like *axis* of inflorescence.

Example.—The Fig.

2. *Sorosis.*—Collection of achenes, drupes, or berries, with persistent, succulent, floral envelopes or bracts.

Example.—Mulberry.

TABLE OF FRUITS.

I. DRY FRUITS.			II. SUCCULENT FRUITS.	
1. INDEHISCENT.	2. DEHISCENT.		1. INDEHISCENT.	2. DEHISCENT.
	a. Monocarpellary.	*b.* Polycarpellary.		
Achene.	*Follicle* (dehisces by one suture only).	*Siliqua* and *Silicula* (composed of two carpels which split longitudinally, and have a false partition or replum).	*Drupe* (pericarp has three distinct parts—epicarp, mesocarp, endocarp).	*Dehiscent Drupe*—*Ex.*—Walnut.
Nut.	*Legume* (dehisces by both sutures).	*Schizocarp* (splits into separate Achenes).	*Berry* (pericarp has only two distinct parts—a skin or epicarp, and a succulent part in which the seeds are embedded).	*Dehiscent Berry*—*Ex.*—Squirting Cucumber.
Caryopsis (a variety of Achene with the pericarp adherent to the seed coat.	*Lomentum* (a legume which splits *transversely* into indehiscent one-seeded portions). Is just a monocarpellary schizocarp (*see b*).	*Capsule* (any dry dehiscent syncarpous fruit *not* a siliqua, or silicula, or schizocarp).		

Persistent Parts in connection with Fruit—

1. Calyx.—Often persists.

2. Involucel.—A persistent bract cup which surrounds each floret in Dipsaceæ.

3. Cupule.—A cup, made of bracts, which forms round the lower portion of the fruit in Oak, Hazel, Beech, &c.

4. Succulent Receptacle.—As in Strawberry, &c.

The Ovule,

Or Immature Seed or Macrosporangium of Phanerogams.

Parts.—Shown below in the diagram of inverted ovule of Angiosperm (Fig. 48). In the Gymnosperms the ovule has a very short stalk or funicle and only *one* coat, the nucellus is large, and the embryo sac is at some distance from the micropyle. In this class, prior to fertilisation, a prothallus (so-called Endosperm) forms in and fills up the embryo sac.

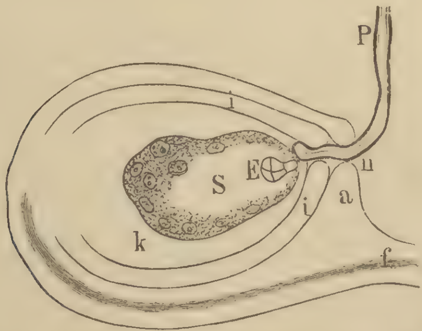

FIG. 48.—Diagram of an Angiospermous ovule shortly after fertilisation: *a* outer, and *i* inner integument; *f* funicle; *k* nucellus. *S* Embryo-sac in which *E* is the embryo developed from the fertilised oosphere (egg). The sac also contains the endosperm-cells which are being formed by free cell-formation. *P* The pollen-tube, passing through the micropyle, *n*. See also Fig. 73. (After Prantl.)

THE SEED.

Definition.—The ripe ovule.
Occurrence.—In Phanerogams.

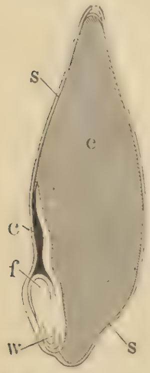

FIG. 49.—Longitudinal section of grass seed. *f* Plumule, *w* Radicle, *c* Cotyledon of embryo, *s* Seed-coat, *e*, Endosperm.

Parts.—Usually there are three parts.—1. Embryo; 2. Endosperm, or tissue containing reserve food stuff outside 1; and 3. Spermoderm, or seed coat, which may be double (testa and tegmen). A seed made of those portions is said to be *albuminous*. (Fig. 49). When there are only two parts Embryo and Spermoderm, the seed is *exalbuminous*. (Figs. 50 and 51).

Example.—Pea.

In this latter case the necessary food for the embryo is stored up in its own cotyledons or seed leaves.

Perisperm.—The name given to the food containing tissue of some seeds, which has been derived from the *nucellus* of the ovule.

BUDS.

Definition.—A bud is a branch, or terminal portion of a main axis, in its earliest or first stage of development. It is produced asexually, and is capable of developing into a plant like its parent, and may.

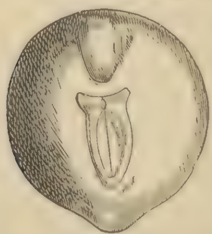

FIG. 50.—Exalbuminous seed of Pea, from exterior.

FIG. 51.—Embryo of Pea after removal of skin of seed, showing the two bulky cotyledons, plumule and radicle.

or may not, normally separate from it. Buds are either unicellular or pluricellular (usual). Only in the lowest plants, such as Yeast (*Saccharomyces*), do we find unicellular buds. (Fig. 52).

Forms of Bud—

1. Gonidium.—*Unicellular* bud. It is a propagative cell, with or without a wall, which separates from its parent.

Example.—In Thallophytes.

Frequently gonidia are formed within a receptacle or bud sac (*Gonidangium* or Endogonidium) by free cell formation,

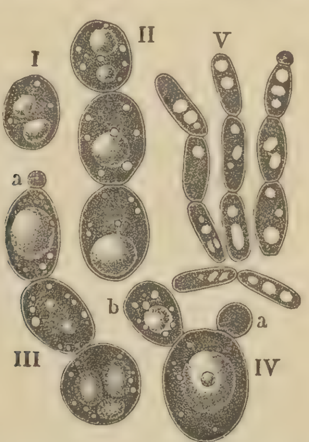

FIG. 52.—YEAST FUNGI.—I.-IV. Beer fungi (*Saccharomyces cerevisiæ*, Meyen), showing the process of budding. V. *Saccharomyces Mycoderma* (Rees), × 1000 times. (After Behrens.)

and are then distinguished as *Endogonidia ;* or on a special stalk (bud-stalk or *Stilogonidium*), when they are known as *Stilogonidia*). Motile gonidia are termed *Zoogonidia.*

2. Gemma.—A *pluricellular* propagative bud, without any differentiation into stem and leaf (such as characterises the following, 3 and 4). It separates from its parent.

Example.—Marchantia (see Fig. 53).

The gemmæ pass, without demarcation, into the gonidia on the one hand, and bulbils on the other.

3. Bulbil.—A deciduous leaf-bud capable of propagating its kind.*

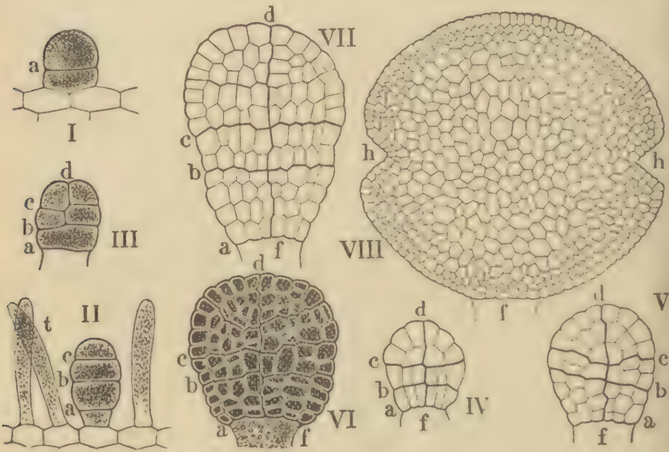

FIG. 53.—*Development of gemmæ in* Marchantia polymorpha.—I. Epidermic cells, upon which lies the apical cell from which the gemma is developed; the first two segments are already present, separated by a partition at *a*. II. The same, with two additional segments (*b c*) developed parallel to *a*. III. The same, showing the segments divided by a vertical partition, *d*. IV.-VII. Successive stages of development. The segments increase in number, the primary partitions being marked by stronger lines; the cell (*f*), upon which the whole structure rests, can now easily be distinguished. In VI. and VII. a multicellular tissue has been formed. In VIII. we have the full-grown gemma, composed of a tissue of parenchyma cells, and slightly cleft at *h* (*i.e.*, between the segments *b* and *c*). The cell-contents are indicated in I., II., III., and VI.; they are omitted in the other figures for the sake of clearness. I.-VII. × 600 times; VIII. × 200 times. (After Behrens.)

4. Leaf-bud.—A bud, not normally deciduous, which shows differentiation into stem and leaf.

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* In Chara, the "amylum-star" bud is often called a bulbil. *It* is a tuber-like separating propagative body.

The Leaf Bud.

Structure.—An apical piece of young stem with extremely short or undeveloped internodes, and young leaves folded over its apex. Buds which persist through the winter (usual case) are provided with scaly or stiffly membraneous, dry, viscid, hairy, or smooth protecting leaves, called *bud scales*, which usually fall off in the spring, when the enclosed parts begin to grow vigorously. These bud scales have usually corky cells. The tissues of the parts of the bud within the scales, capable of extended growth, are all of the *formative* description (*see* page 36).

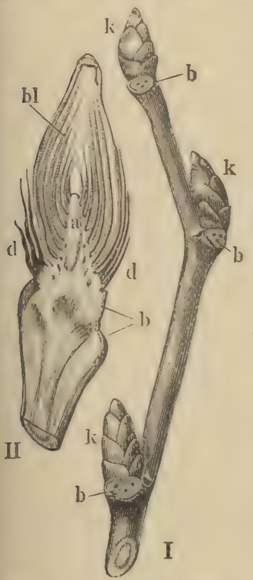

FIG. 54.—Elm (*Ulmus campestris*). I. Shoot, with leaf-buds; nat. size. II. Leaf-bud in longitudinal section, × 3 times. *k* Buds, *b* Leaf-scar, *d d* Bud-scales, *a* Axis of branch yet in the bud. (After Behrens.)

Positions.—*Terminal* and *lateral.* The *lateral* buds in Phanerogams are almost always *axillary*, *i.e.*, in the axil of a leaf,* but in cryptogams the *extra*-axillary position is the more usual one. The terminal bud gives rise to increase in length of axis, and the lateral bud gives rise to branching.

Kinds.—1. Purely vegetative; axis with indefinite growth; 2. Flower Bud with definite growth; 3. Mixed Bud.

Development.—In ordinary bud formation the leaves are produced from the axis acropetally.† They arise at the growing point of the shoot as superficial

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* With few exceptions, in Phanerogams, buds are developed in the axils of *all* leaves except the floral. They are, however, absent from the axils of some of the normal leaves of conifers, &c. A few plants develop buds upon their leaves.

† In flower-buds the development may not be wholly acropetal.

outgrowths, but, as a rule, the deeper layers of tissue also co-operate in their formation. The development is exogenous, there being, from the first, complete continuity of the homonymous layers of tissue of the leaf and of the axis (see Fig. below).

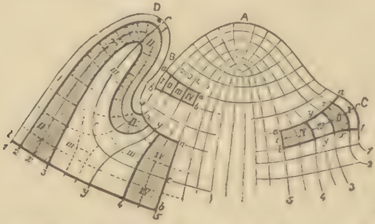

FIG. 55.—Diagram illustrating the mode of origin of leaves (with alternate arrangement) from the growing point of a Phanerogam. *A*, apex of the growing point. *B*, *C*, *D*, various stages in the origin of a new leaf: the arabic numbers, and shading, indicate how the individual layers of cells take part in the origin of the new leaf. It is clearly indicated in this diagram that no periclinal divisions appear in the cells of the dermatogen. (After Sachs.)

Ptyxis, or the folding of the leaves in the bud:—

1. Plane.—When the leaf is not folded at all.
2. Reclinate.—Apex of leaf *folded over* to base.

FIG. 56.—Reclinate Vernation.

FIG. 57.—Circinate Vernation.

FIG. 58.—Conduplicate Vernation.

FIG. 59.—Convolute Vernation.

3. Circinate.—Leaf *rolled up* from apex to base, *e.g.*, Ferns.

4. Conduplicate.—When the margins or two edges of the leaf are brought together.

FIG. 60.—Involute Vernation.

FIG. 61.—Revolute Vernation.

5. Convolute.—When the leaf is *rolled* from side to side.

6. Involute.—When the *two* margins or sides of the leaf are *each rolled* inwards *on the upper surface.*

FIG. 62.—Plicate Vernation.

7. Revolute.—When the *two* margins are *rolled* backwards on the under surface.

8. Plicate.—Plaited.

9. Crumpled.

Example.—Petals of Poppy.

Vernation, or Leaf-Grouping in the Bud.*

1. Imbricate.—When the leaves *overlap* each other. This is the usual kind of vernation in the alternate, and is also common in the whorled phyllotaxis (see page 59).

FIG. 63.—Vernation and Æstivation.—I. Valvate; II. Twisted; III. Imbricate.

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* *Æstivation* is the term usually applied to leaf-grouping in the flower-bud. Besides the varieties 1, 2, 3, above, there is the Vexillary or *Papilionaceous* æstivation of the petals of the Leguminosæ (see Fig. 67), and Twisted or *Contorted*, which is just imbricate, but the whole whorl has got a *twist* round. (See Fig. 63).

2. Valvate.—When the leaves do not overlap, but simply meet each other at the edges. Common in whorled and oppositely arranged leaves.

FIG. 64.—Induplicate Vernation.

FIG. 65.—Equitant Vernation.

3. Induplicate.—When the margins are directed inwards. This is just a modification of 2; it is not common.

4. Equitant.—When one leaf embraces both edges of

FIG. 66.—Half-equitant Vernation.

FIG. 67.—Vexillary Æstivation.

another; and Half-Equitant, when it embraces only one edge of its opposite neighbour. These forms are usually produced when the leaves are arranged in the distichous fashion (see page 60).

Bulb. (*See* page 59).

APPENDAGES OF THE PLANT OTHER THAN LEAVES OR BRANCHES.

The Hair and Emergence. (See page 44).

The Sporangium.

A unicellular or multicellular body, the direct or indirect product of a sexual act, producing in the former case by endogenous division* of its single protoplasmic mass, and

* *i.e.*, Free Cell Formation. (*See* page 26).

in the latter case of central mother cells, true spores, and thereby becoming a spore-sac.

Spore.—A single cell* that becomes free,† and is capable of developing directly into a new individual. There are two kinds :—

1. Gonidia.—Spores asexually produced, by abscission, or inside a cell (*see* page 71).

2. True Spores.—The product, directly or indirectly, of a sexual act.

A *Zygote* is a true unicellular spore which results directly

FIG. 68.—Formation of spores in the asci of *Peziza aurantium* ; × 600 times. *a* (1, 2, 3) Asci in various stages of development ; *sp* Hyphal filaments forming Hymenium. (After Behrens.)

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* Originally and typically unicellular, but may become multicellular by the production of two or three cells before directly developing into a new individual.

† The macrospore (embryo-sac) of Phanerogams is an important exception to this rule. It does not become free.

from the union of two gamete or sexual cells *similar in appearance*. This only takes place in lowly plants; in the higher forms the sexual act (accomplished by *unlike* elements) brings about either the development of a pluricellular *sporocarp*, or a *sporophyte* which is specially destined sooner or later to produce sporangia with true spores.

The exceptional spore, which does not become free from the sporangium, has always a delicate wall, but the others have usually two coats—Exosporium and Endosporium (Extine and Intine in pollen grains), the former of which is strong, comparatively thick, and corky. The spore germinates by the rupture of the outer and protrusion of the inner coat with contents.

Forms, &c., of Sporangia:—

1. *Ascus*.—A single large cell, usually the swollen extremity of a hyphal branch (*see* Fig. 68) in Ascomycete Fungi, within which spores (typically 8) are formed by free cell formation.

FIG. 69.—I. Pinna (*n*) of *Polystichum spinulosum* with sorus (*h*). II. Sporangium from the side. III. The same from behind. *p* Stalk; *r* Annulus; *s* Spores. I. × 10 times; II. III. × 200 times. (After Behrens.)

2. *Zoosporangium*.—A sporangium producing motile spores (*zoospores*). Occurs in, and is confined to, the Thallophytes.

Zoospores.—Wall-less cells (formed either by the endogenous division, or by the rejuvenescence, of a cell), that move about through the water into which they arrive by means of cilia.

3. *Typical Sporangium* (that of Ferns).—A capsule when mature with a wall of a single layer of cells, stalked, rarely sessile. The spores originate by the endogenous division of central mother cells which have been produced by the repeated bipartition of a single cell, or more rarely, group of cells, either being known as the *Archesporium*. A group of sporangia receives the name of *Sorus*. In most cases in Ferns a complete or incomplete ring of the wall cells are thickened to form an *Annulus*, which effects the opening of the sporangium when ripe, by rupturing at certain spots and curling back. (Fig. 69).

Indusium.—The covering of a sorus, or in higher plants, of each sporangium.

Note.—All the families *below* and *including* Filicineæ (Ferns), with the exception of Salviniæ and Marsiliæ, are, *Homosporous*, *i.e.*, produce *one* type of Sporangia and Spores. The Class Equisetinæ and *order* Lycopodiaceæ are also Homosporous, but *all others* above the Filices, including the exceptions named, are *Heterosporous*, *i.e.*, produce two kinds of sporangia (*Macro-* or *Megasporangia* and *Microsporangia*) with correspondingly distinct kinds of spores (*Macro-* or *Megaspores* and *Microspores*).

4. *Sporangia of Heterosporous Ferns.*—Are capsules enclosed in a unilocular case, which is covered by a special development of the indusium known as a sporocarp (so-called). The macro- and microsporangia either occur *together* in groups or sori, surrounded by the same sporocarp (Marsiliaceæ), or they are in *separate* groups, which are enclosed in *different* sporocarps (Salviniaceæ). The mature microsporangium contains 64 spores, the macrosporangium only one ripe spore. The micro- and macrospores when set free germinate, and produce small male and female prothallia* respectively, which project but little from the spores.

5. *Sporangia* (Heterosporous) of Selaginella. — The sporangia are situated in the axils of the fertile leaves or

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* *Prothallium.*—A thalloid oophyte (Muscineæ to Gymnosperms) *or its homologue* (antipodal cells in embryo-sac, and vegetative cell in pollen grain of Angiosperms).

Oophyte.—Defined by Balfour "as the segment or stage of life cycle of a plant that bears sexual organs" (Muscineæ to Gymnosperms), or its homologue in Angiosperms as above.

sporophylls at or near the apex of the stem, the whole forming a kind of cone or spike. The micro- are usually placed higher up the shoot than the macro-sporangia, or on the opposite side. Each of the latter, when mature, has four macrospores (Fig. 70).

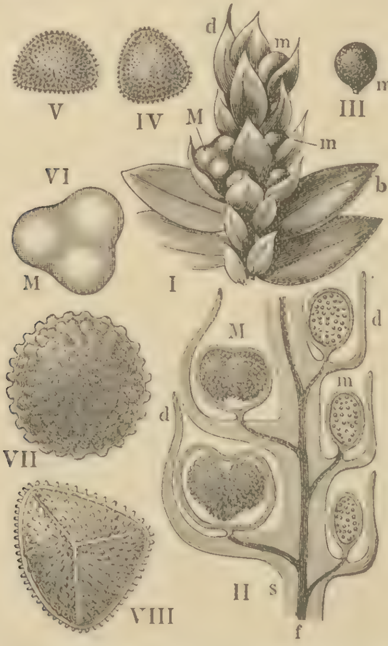

FIG. 70.—*Lycopodineæ.*—I-VII. *Selaginella pubescens.* I. Lower part of the spike with macro- and microsporangia; × 10 times. II. The same, longitudinal section, somewhat diagrammatic; × 20 times. III. Microsporangium; × 20 times. IV., V., Microspores; × 300 times. VI. Macrosporangium; × 20 times. VII. Macrospore; × 70 times. VIII. Spore of *Lycopodium complanatum*; × 300 times. *s* Stem; *f* Vascular bundle; *b* Leaves; *d* Leaves of the spike; *M* Macrosporangium; *m* Microsporangium. (After Behrens.)

The tapetum persists till the spores are ripe in Selaginella, while in ferns it is destroyed during their formation (see Fig. 71 and glossary).

6. *Sporangia* of Gymnosperms :—

   a. Microsporangia or pollen sacs, with microspores or pollen grains.

   b. Macrosporangia or ovules, each with one macrospore or embryo-sac.

For consideration of these, see under the Plant Type, *Pinus.*

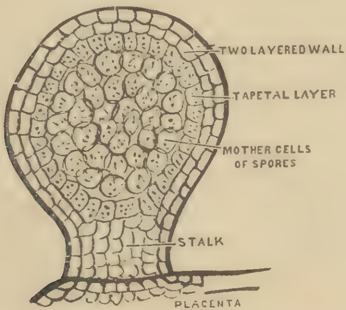

FIG. 71.—Young Microsporangium of Selaginella. This diagram will also do for a young Macrosporangium; but latterly, in *its* case, one of the mother cells grows much more vigorously than the rest, and divides up into four macrospores, while the other mother cells remain small and undivided.

7. *Sporangia* of Angiosperms :—

   a. Microsporangia or pollen sacs, with microspores or pollen grains.

   b. Macrosporangia or ovules, each with one macrospore or embryo-sac.*

For consideration of these, see under the Plant Types.

Placenta.—The tissue from which the sporangia arise. When the sporangium, however, is sunk in the substance of its origin, there is usually said to be no placenta.

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* The ovule or macrospore of Phanerogams may be straight or curved or inverted (common).

THE SEXUAL ORGANS.

In the higher plants, two different forms of cells are separated off from the general body, for the purpose of reproduction. These are *sperms* and *ova* (eggs). It is from the latter that the new individual arises, but only as the result of contact, stimulation, and impregnation by the former. In some of the lowest plants, however, these *gamete* or sexual cells are outwardly alike, and conjugation is the name applied to the sexual act which they perform.

Pollinodium.—In the Ascomycetes (Fungi) this is the name applied to the usual male sexual organ, because it is more or less tubular, and directly or by means of an outgrowth impregnates the female sexual organ (see Figs. 92 and 93).

Spermagonium.—A cup-shaped receptacle in which *spermatia* or non-motile male gametes are abjointed on stalks known as *sterigmata.*

Example.—Higher Thallophytes.

Antheridium.—A male sexual organ which produces in its interior spermatozoids (ciliated motile male gametes), or rarely spermatia (motionless male gametes) (see Figs. 83, 124).

Archicarpium (carpogonium).—A female sexual organ, consisting of a cell or group of cells, and fertilised by an act of *conjugation* (see page 94), *i.e.*, it has no special receptive and transmitting apparatus. The result of its growth after fertilisation is a sporocarp or body, which serves for the formation of spores, and which ceases to exist after having, with comparative rapidity, formed a number of spores.*

Example.—In Ascomycetes.

Procarpium.—Unicellular or pluricellular female sexual organ, having a peculiar thread-like receptive apparatus (*trichogyne*). Its lower portion is like the archicarpium, *i.e.*, its protoplasm is not rounded off to form an oosphere

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* Do not confound this, the true sporocarp, with the so-called sporocarp of Heterosporous Filicineæ (see page 79).

or egg, as in higher plants; and, after fertilisation, it developes a sporocarp.

Example.—Polysiphonia.

Oogonium.—A more or less spherical female sexual organ, containing one or more ova or oospheres. There is no differentiation of this organ as in the next case, into neck and venter cells.

Examples.—Vaucheria, Pythium (Figs. 83, 92).

Archegonium.—A female sexual organ, with a neck portion pierced by a canal leading to a venter, containing one ovum and a smaller cell above it (ventral canal cell). After fertilisation, the embryo is developed within the venter (see Figs. 105, 109).

Example.—From Muscineæ upwards, but in Angiosperms the archegonium is *extremely modified*, the neck being formed by only two cells (wholly or partially naked), called the *synergidæ*, and the ovum lies close beneath, or between, these in the protoplasm of the macrospore or embryo-sac (see Fig. 73).

PHYSIOLOGY.

1. Nutrition of Plants.

Chemical Composition of Plants.

1. *Water.*—Forms on an average fully 70 per cent. of the stems and leaves of herbaceous plants. Many fruits and water-plants contain 90 per cent., but ripe seeds have only an average of about 13 per cent. of water.

2. Solid material, normally dissolved or undissolved in 1:—

(*a.*) *Organic Compounds.*—Chiefly *carbohydrates* (starch and its isomers and sugars), fats,* and *albuminoids*, the former two composed of the elements, Carbon, Hydrogen, Oxygen, and the latter of these plus Nitrogen and a trace of Sulphur and Phosphorus. Besides those substances there are waste organic products composed in the main of the same elements, as gums, resins, latex, tannin, vegetable acids, &c.

(*b.*) *Mineral Matters.*—The incombustible portion of the *Ash* of plants, which contains a large number of elements, the principal of which are:—*Potassium*, *Calcium*, *Magnesium*, *Iron*, *Phosphorus*, *Sulphur*. Sodium, Silicon, Chlorine. The elements in italics appear to be essential to all plants along with those mentioned above under ***a***.

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* In the Fungi, fats and oils very generally replace carbohydrates.

Table

SHOWING PERCENTAGE COMPOSITION OF WHEAT SHOOT AND SEED, *after removal of the water.*

	Wheat grain.	Wheat Shoot (stem and leaves.)
Carbon, ...	46·1	48·4
Hydrogen, ...	5·8	5·3
Oxygen, ...	43·4	38·9
Nitrogen, ...	2·3	0·4
Ash (including Sulphur and Phosphorus), . .	2·4	7·0
	100·0	100·0

The Food of Plants.

Carbohydrates, fats, albuminoids; and sulphates of one or more of the elements *italicised* in 2 (*b*) above, and nitrates of one or more of the same, and phosphates of one or more of the same; * also water, which is, besides being an important food in itself, a source of food elements, and a necessary vehicle in digestion, circulation, &c.

The Sources of the Food of Plants.

1. In *green* plants the Carbon of the organic compounds named above is obtained from the carbon dioxide (CO_2) of the atmosphere; the Hydrogen † and Oxygen are chiefly procured from the water; the Nitrogen from the nitrates and ammonia compounds in the soil (certain leguminous plants, however, can obtain it from the atmosphere as a result of *symbiosis* ‡); sulphur from soluble sulphates, and phosphorus from soluble phosphates in the soil. These elements (or simple compounds of) the chlorophyll containing plant in its own body manufactures, or builds up into the necessary organic food stuffs. The carbon dioxide which is the source of the carbon is almost wholly taken into the green plant through the stomata of the leaves. All

* Or sulphates, phosphates, and nitrates of any non-essential element present in the soil, as sodium, &c., that will furnish a soluble compound, or of ammonia.

† Perhaps also from ammonia compounds in the soil.

‡ The living together of dissimilar organisms.

the other constituents mentioned here and in 2 below come in through the roots dissolved up in the water which they absorb.

Parasites and *Saprophytes* (see pages 12, 56, 119), take up their Carbon, Hydrogen, Oxygen, Nitrogen, in the form of complex organic compounds,* which they obtain in their living or dead hosts.

Carnivorous plants, like Drosera, procure a certain amount of their essential nitrogenous organic compounds from the bodies of insects and other small animals which they capture and digest.

2. The sources of the inorganic elements—sulphur and phosphorus—have already been indicated. The essential metallic elements of the food, potassium, calcium, magnesium, iron, are procured from the soil in combination with sulphates, phosphates, nitrates, carbonates, chlorides,† &c., and the potassium (and sodium) may also pass in as a silicate.

Food substances used in the making of Protoplasm.—Albuminoids, water, ash.

Food substances which go to form cell wall.—Carbohydrates, water, ash.

Functions (Probable) of Food Elements.—Carbon, Oxygen, Hydrogen, Nitrogen, form the bulk of the plant. Sulphur and Phosphorus are essential constituents of proteids. Phosphorus also, when combined with calcium and magnesium, has something to do with the solution of albuminoids. Potassium in some combination appears to have an important function in green plants in connection with the elaboration of organic food substances. Calcium is of vast importance in helping the green plant to maintain a healthy condition. It combines with the vegetable acids, oxalic (usual), and carbonic, which are excrements or resultants from protoplasmic waste, arising in the processes of respiration, digestion, &c., and removes them out of the way of the circulation of the living matter, fixing them in

* As proteids, sugar, &c.

† Chlorides of magnesia and calcium seem to be injurious to the plant.

special cells or cell walls, as solid crystallised oxalate or carbonate of lime compounds.

Iron is also necessary to the health of green plants; without it, as an almost invariable rule, the chlorophyll of the chloroplastid will not properly form.

Methods of Absorption of the Food Elements.—The roots or parts acting physiologically as such take in the material in the liquid state, by, it is usually said, simple osmosis and imbibition. But the real great cause of the absorption of fluids appears to lie directly in the living protoplasm, which draws them in by simple vital attraction, and partially retains or stores them in its interior, forming vacuoles (see pages 5, 19).

From the root hairs of soil roots there is always excretion of acids going on which effectively aid in the solution of many particles of soil; that is to say, we have in this case digestion occurring outside of the plant as well as inside.

The carbon dioxide is absorbed by green leaves, chiefly through their stomata, of course in the gaseous form, by attraction and diffusion, other gases going out when the atmospheric gases go in. The entire body, however, of young plants or parts of plants can absorb gases.

Gases pass through plants mainly by diffusion through the cell walls, &c.

There is never ingestion of solids by plants.

Metabolism.—The *life processes*, *constructive* and *destructive*, of the organism.

Constructive Metabolism.

Assimilation, or elaboration of organic compounds by green plants.

1. *Non-Nitrogenous* Organic Substances.—The CO_2 which is taken into the leaf is, under the action of daylight and the vital influence of the chloroplastids, evidently made to react with water, so as to produce the chemical changes expressed in the following equations:—

1st Part.—CO_2 + H_2O = CH_2O + O_2

(Carbon dioxide) and (water) gives (Formic aldehyde) and Oxygen, which is evolved.

$$\text{2nd Part.—} 6\,CH_2O \quad = \quad C_6H_{12}O_6 \,*$$
(Aldehyde) gives (Glucose).

This glucose would at once either be dissolved and carried away through the plant, or converted there and then into starch by dehydration :—

$$C_6H_{12}O_6 \quad - \quad H_2O \quad = \quad C_6H_{10}O_5$$
(Glucose) *minus* (water) gives (starch).

2. *Nitrogenous* Organic Substances.—Also takes place in green plants in the leaves under the influence of light and chloroplastids. From the nitrates taken in from the soil ammonia is prepared, which, while in the nascent state (?) combines with the aldehyde, produced as shown in 1. above, forming an *amide* (soluble nitrogenous compound). This amide by combining with more aldehyde and sulphur, and very usually with also a trace of phosphorus, forms a *proteid* substance.

The Function of Chlorophyll.—It absorbs certain rays of light, and thus enables the plastid with which it is connected, and the protoplasm of the cell in which it lies, to avail themselves of the radiant energy of the sun's rays for the construction of formic aldehyde from CO_2 and water, and of amides from ammonia and aldehyde.

The Distribution of the Organic Substances through the Plant.—The sugars and amides travel in the parenchymatous tissues, the former being, here and there, generally converted into the solid form (starch) as it goes along, and the latter into solid proteids (aleurone, &c.), or they are directly absorbed into the substance of the protoplasm. The sieve tubes likewise distribute proteids (which they also largely elaborate ?), acting however as temporary reserve organs.

Reservoirs of Nutriment.—The excess of elaborated food stuffs are stored up in seeds for the next generation, and in bulbs, tubers, corms, or rhizomes, &c., in biennial or perennial plants, for the use of the vegetable itself in the next active growing season. For this purpose the excess of sugars, amides, and dissolved proteids which pass to

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* *i.e.*, Six molecules of formic aldehyde under the influence of light and the completely developed chloroplastid, are united or chemically built up in such a way as to constitute one molecule of glucose or grape sugar.

these organs are usually changed by the protoplasm of the cells into which they arrive, into solid or more or less indiffusible substances, viz., the sugars into starch, and the soluble nitrogenous compounds into aleurone grains and crystalloids. The starch may in some unknown manner pass into fat, and the latter material may also be formed by the degradation of proteids.

Digestion.—Is the conversion of a body which is primarily more or less insoluble and indiffusible into a substance that is perfectly soluble and diffusible. We have digestion outside the plant around the young roots (see page 87). Inside the plant the *starch*, when required as food, is changed by an unorganised ferment into *sugar* (glucose usually), and the solid proteids by other ferments, with very probably the aid of the globoids, &c. (see page 18), are also converted into a soluble state. Fat is put into a condition fit for digestion by another unorganised ferment known as *emulsion*.

Destructive Metabolism.

Living protoplasm is constantly undergoing spontaneous decomposition, giving rise to cellulose, from which the cell wall is made, and to amides. (The latter, therefore, in the plant, form analytically as well as synthetically.) The self-decomposition of the protoplasm also gives rise to unorganised ferments (which are proteids allied to peptones), by the action of certain of which starch is changed into glucose, and by others, glucose into cane sugar; the latter into glucose, and proteids into peptones, and exceptionally (in some lowly Fungi) sugar into CO_2 and alcohol (fermentation).

Excretions.—Plants retain in special parts of their bodies most of their excretory nitrogenous compounds and derivatives of these, and also products of the degradation of cellulose, &c. &c. The waste gases and vapours they give out by respiration, and the liquids by transpiration, evaporation, and direct excretion.

Respiration.—Consists in the *taking in* of the diluted oxygen gas of the atmosphere by the living protoplasm, and the *evolution* of CO_2 and watery vapour. Every kind and section of living protoplasm, animal and vegetable, respire alike. It is a wasting process, and is the primitive source of

the decomposition of the protoplasm, by which, and the regular renewal of the vital substance by foods, the energy and phenomena of life are maintained. The younger the cell the more active is the process of respiration.

The energy obtained by the metabolic processes is either *accumulated* or at once *dissipated*. The accumulation of energy is the necessary accompaniment of constructive metabolism, and its dissipation of destructive metabolism. Energy is expended on growth, movements, and heat, and in a few rare cases on light (some Fungi) and electricity.

Transpiration.

Definition.—The exhalation of watery vapour from the plant by the process of evaporation.

The leaves are the principal organs of transpiration. The water is chiefly transpired through the stomata and lenticels (see pages 42, 46). The air stomata are the direct controllers of the process, and as these are normally much more abundant on the under than upper side of the leaf, it follows that more transpiration goes on on the under than upper surface of the blade.

Movement of Sap in the Plant.

There are two currents of fluid in the plant—(1) The *ascending* current of *crude* sap (water with mineral matters, &c., in solution). This passes upwards from the roots to the leaves. (2) The *descending* current of *elaborated* sap (containing plastic materials, or manufactured organic food stuffs, &c.). This current spreads everywhere throughout the living vegetable the necessary foods, and brings reserve material to the storing organs, so that its course is in reality really horizontal, and ascending as well as descending.

How is the Water taken in from the Soil.—It is commonly said that the water (crude sap) is absorbed by osmosis and carried upwards by that process, and also by imbibition: but the real cause is a vital one, and lies in the well known attraction and affinity of the living protoplasm for watery fluids. The water taken in by the root-hairs passes up into

the cortical parenchyma, and then mainly goes into and rises up through the xylem parts of the root vascular tissue, and from these, which are continuous with the xylems of the shoot, it arrives ultimately in great bulk into the principal transpiring organs, the leaves.

The Ascending Water Streams.—There is the *slow* ascent from neighbouring living cell to neighbouring living cell, and the much more *rapid* movement in which the great bulk of the water absorbed takes part from the living absorbing cells of the root up through the long chain of wood tissue (by so called imbibition) to the living mesophyll cells of the leaf, against which the ultimate prolongations of xylem terminate.

Cause of the Ascent of Water.—Protoplasmic attraction, directed and stimulated by transpiration.

The water contained in the superficial living cells of the leaf undergoes evaporation into the atmosphere (*i.e.* transpiration). Then the protoplasms of these cells draw with increased force the water out of the cells lying within, so as to restore their original equilibrium, and the latter cells draw from others within them, and so on. But owing to the tenacity with which protoplasm holds water this ascending movement would be altogether *slow* if it were not for the dead xylem tubes and elongated tracheids that furnish a passage fairly free from obstacles through which the necessary fluid to supply that removed by evaporation can be drawn with comparative rapidity direct, to a great extent, from the absorbing cells of the root itself.

The *Current of Elaborated Sap* is a slow and rather irregular one, and appears to be directed solely by protoplasmic attraction. It mainly passes down through the phloem sieve tubes and parenchyma.

II. Growth.

Brings about *increase in bulk* and *permanent change in form.*

Growth is *dependent*, as far as *material* goes, on *constructive* metabolism, and as far as the necessary *energy* is concerned, on *destructive* metabolism. It can only go on within certain limits of temperature, and only when the cells concerned

are in a *state of turgidity* through an adequate supply of water.

The power of growing is normally possessed by each individual cell only during a particular period of its life. The egg of plants is, however, a notable exception. Before the time of fertilisation it has ceased to grow; but after fertilisation,* it grows actively again and gives rise to the embryo. Another exception is found in the mature cells of the ovary wall when they grow again to form the fruit. Injury to an organ also frequently induces the growth of neighbouring cells.

Growth is variously directed by internal and external stimuli.

Mechanics of Growth.—The protoplasm, which at first completely fills the cell, does not increase at all so rapidly, or to the same extent, as the wall; therefore, spaces are formed in its interior which are filled simultaneously as they arise with water attracted from the outside (*vacuolation*), and as the cell further increases, the several vacuoles coalesce to form one large vacuole. The hydrostatic pressure of the contained water (or turgid condition of the cell) distends the wall, and this distension is gradually rendered permanent by growth, *i.e.*, by actual additions to the substance of the wall, and further distensions are in their turn again rendered permanent by this actual growth. The additions are laid on by the pressing protoplasm, partly by intussusception, but perhaps in the main by apposition or accretion (see page 22).

Properties of Growing Parts.—At first the whole plant grows, but latterly, as a rule, the capacity for growth is possessed by certain parts only, *e.g.*, apices of roots and shoots bringing about growth in length, and incalated zones bringing about growth in thickness or interposition of new tissues, or further development of old ones. The growing internodes are *very flexible*, but *very imperfectly elastic*, so that they retain, if strongly bent, a permanent curvature. The maximum of extensibility and of flexibility exists somewhat behind the *punctum vegetationis* (apex of initials), that

* When, however, by the sexual act it has practically become a new cell.

is, in the region of most active growth. As tissues become mature, their extensibility and flexibility diminishes, and their elasticity increases.

Tensions in growing Parts.—1. Turgidity, which is the essential condition of normal growth. 2. Tensions in directions—longitudinal and transverse. The turgid pith of the stem of the young plant is prevented from elongating to its full extent by the rigidity of the outer tissues (*positive* tension), and the external tissues are stretched by the pith, *i.e.*, they are in a state of *negative* tension. The longitudinal tension is much less considerable in roots.

The transverse tension of stems (readily shown to exist by taking off a ring of cortex and attempting to replace it, when it will be seen to be impossible to make the two ends meet) is due to the fact that the turgid parenchyma of the interior tends to expand, not in length only, but in all directions; and that the epidermal parts become narrow in consequence of being stretched by the longitudinal tension. In roots, the transverse, like the longitudinal tension, is scarcely appreciable.

In the growth in thickness of Dicotyledons and Conifers, the cambium sets up transverse tensions between the inner and outer tissues, the effect of which is to stretch the latter in the peripheral direction, so that rupturing and scaling off of the old or most external bark is produced.

Nutation or Movements due to Growth.—1. Simple—*Hyponastic* when growth is more rapid on the under than upper side of plants, and *epinastic* when *vice versâ*. The plumule of the Dicotyledon embryo is first epinastic; and then afterwards, on germination, hyponastic, until it becomes erect. Leaves in the bud are hyponastic; their unfolding is due to epinasty.

2. Revolving Nutation—Supposed to be induced by the action of gravity on weak, turgid, slender stems and leaves, but no doubt chiefly spontaneous. Twining stems and tendrils exhibit revolving nutation, but the latter in a different direction from the former.

Action of Light.—Seems to retard growth (?), and therefore growing organs usually bend towards the light (*positive heliotropism*), only in a very few cases do they curve away from it (*negative heliotropism*).

Influence of Gravitation (Geotropism).—Roots are *positively* geotropic, *i.e.*, their growing parts in typical cases curve downwards; while ærial typical stems are *negatively* geotropic, *i.e.*, their growing apices curve upwards.

Irritability of Mature Organs.—Due to the contracting of the protoplasm, consequent on irritation or stimulation in turgid parts having elastic or yielding cell walls.

Example.—Sensitive Plants.

To this subject, unfortunately, no more space can be devoted.

III. Reproduction.

Consists in the separation of a part that will normally grow up into a plant like its parent, either directly or after an interval.

Modes:—

1. **Agamogenesis**, or Asexual Mode. — Effected by Gonidia, Gemmæ, true buds, &c., and spores, the latter by growth developing the sexual condition of the plant, or a structure more or *less* like a typical plant structure, *bearing* the sexual organs; while the first three detachments grow directly up into a plant like the parent, without the assistance of any other organ.

2. **Gamogenesis** or Sexual Mode.—The essential characteristic is that each of the two sexual elements (cells) produced is incapable of further development by itself. The male must impregnate or coalesce with the female, and the former incites the latter to development when it has blended with it.

Conjugation.—Union of two *similar* gamete or sexual elements to form a *zygospore*, or sexually produced spore.

Example.—Some Algæ and Fungi.

Fertilisation.—This is the name applied to the sexual union when the gametes, or male and female elements, are *dissimilar*. In this case, the larger is the female and the smaller the male gamete.

When the sexual act is about to take place, the female gamete throws off a portion of its substance called the *female polar vesicle*; and, in like manner, about the same

time, a portion known as the *male polar vesicle* is ejected from the male gamete, after which the two nuclei of the gametes combine in the female body to form the single nucleus of the egg, or fertilised female, which then segments.

Segmentation of the Egg.—Either *holoblastic*, as in ordinary flowering plants and ferns, or *meroblastic*, as in Pinus.

Fertilisation in Angiosperms.

The male sexual element is carried in the pollen tube, which is formed by the germination of the pollen grain; and the female gamete is contained in the embryo-sac of the ovule.

The Pollen Grain.—When mature, is a single cell (rarely septate) with two nuclei, the *smaller* of which is the *generative* element. The wall is differentiated into *extine* (cuticle) and *intine* (cellulose).

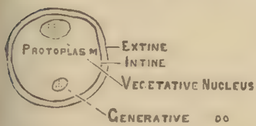

FIG. 72.—Pollen Grain of Angiosperm.

When carried to the ripe stigma of the pistil, the pollen grain, under favourable conditions, produces a tube by the protuberance of the intine, which breaks through the extine at a definite part prepared beforehand. This tube continues to grow, and eat or wriggle its way down through stigma and style to the cavity of the ovary and into the micropyle, and through the nucellus to the embryo-sac wall of the ovule (see Fig. 48).

The Ovule at Time of Fertilisation.—The general structure of the ovule has been already indicated (see page 69). The diagram adjoining shows the appearance and parts of the embryo-sac just before fertilisation.

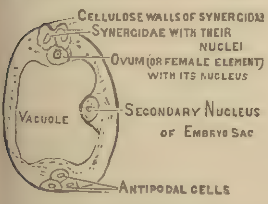

FIG. 73.—Embryo-Sac of Typical Angiosperm at time of Fertilisation.

The embryo-sac developes to this stage as follows:—At first it is an ordinary cell with a single nucleus (*primary nucleus*). It grows vigorously, and becomes a veritable giant compared to its neighbours. When it has nearly reached maturity

its nucleus divides into two, and these again, and so on till eight nuclei are formed. Four of those nuclei travel to the micropyle end and four to the opposite or antipodal end of the embryo-sac. Then one from each group goes back to the centre, and the two coalesce there to form the *secondary nucleus* of the embryo-sac. There are now three nuclei at the antipodal end, which soon surround themselves with walls, remain small, and become the functionless antipodal cells. The three at the micropyle end arrange themselves as shown in Fig. 73, and constitute the egg apparatus: the upper two, with their contiguous protoplasm, being known as *synergidæ*, and the lower as the *ovum*. The latter remains a naked cell until after impregnation, but the former two usually become partially walled with cellulose. These partial walls, which form on the upper side only, are soft and thickish, and grow up through the wall of the embryo-sac.

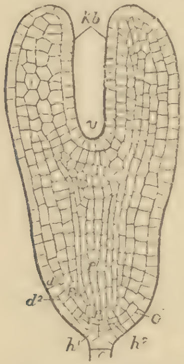

FIG. 74.—Well developed embryo of Capsella Bursa-pastoris (Shepherd's Purse) in longitudinal section. *e*, suspensor, above which is the embryo proper, with *h1* and *h2* rootcap, *d1* and *d2* dermatogen, *pe* periblem, and *pl* plerome, all of radicle; above this, at *v*, is the point of growth of the plumule; *kb* are the cotyledons. (After Prazmowski.

The Process of Fertilisation.—The pollen tube, which has bored its way through the nucellus, gets between the projecting cellulose walls of the synergidæ; and the end of the tube, close to which the generative or male nucleus soon arrives, becomes extremely soft, and lets the contents pass through in thready masses. The male element, or nucleus, fuses with the nucleus of the ovum. When this has been accomplished the act of fertilisation is complete.

Development of Fertilised Ovum into Embryo.—The ovum now surrounds itself with a cell wall, and then grows and divides transversely to form a cell row (*suspensor*), the first, or basal cell, of which becomes attached to the wall of the embryo-sac. The free end cell of the suspensor now grows and divides longitudinally and transversely, forming a cell mass, the upper part (micropyle end) of which developes

into radicle and axis generally, and the lower into one or two Cotyledons (Fig. 74).

Formation of Endosperm.—This is formed in the embryo-sac after fertilisation, and while the development of the embryo is proceeding, as follows:—The secondary nucleus of the sac divides up into many free nuclei, which arrange themselves round the wall, as shown below—

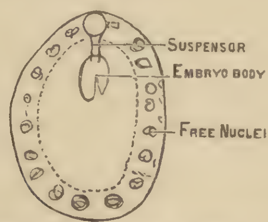

FIG. 75.—Formation of Endosperm in Embryo-sac of Angiosperm.

These free nuclei next surround themselves with walls, and a tissue results, the cells of which divide and multiply, so as to continue and fill up the whole interior of the embryo-sac with this tissue (endosperm) in which the embryo becomes embedded, as indicated in the figures below—

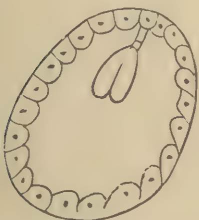

FIG. 76.—Early stage in the Development of Endosperm.

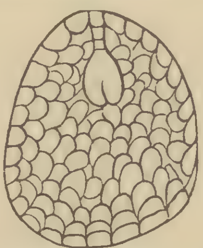

FIG. 77.—Embryo completely Embedded or Inclosed in Endosperm.

The embryo-sac grows during the development of the embryo and endosperm.

The complete embryo now follows one of two courses—it either remains small and ceases to grow any further till

germination, or it keeps on growing and transfers all its endosperm material into the substance of its greatly expanded cotyledons, which now become the storehouses of the nutriment destined for use at germination. In the former case we get a seed consisting of spermoderm (the dried-up ovular coats and nucellus), persistent endosperm, and embryo, that is an albuminous* seed; in the latter, only spermoderm and embryo, with thick bulky cotyledons, in which the material of the original endosperm is stored, that is, an exalbuminous seed (see page 70).

An embryo, at all comparable with that of Phanerogams, never forms below the Muscineæ, and a *typical* embryo is only produced in ferns and in the plants higher than ferns.

Alternation of Generations.

Definition.—The alternation of the oophyte and sporophyte† stages in the development and generation of plants.

In the Fern, in which we have perhaps the most typical case, the fern plant is the sporophyte, and the *green independent* prothallium the oophyte. In the higher plants, the *oophyte* becomes simply an *appendage*, or mere rudiment of an appendage, on the sporophyte; while, on the other hand, in the plants lower than the ferns (Muscineæ) the *sporophyte* is simply an *appendage* to the oophyte.

Apogamy.—Loss of sexual function; the sexual organs are present, but functionless.

Parthenogenesis.—Just apogamy, but the oosphere or ovum of the female develops into the embryo or normal product of fertilisation without a preceding sexual act.

Example.—Not uncommon in Thallophyta.

Apospory.—Loss of the power of producing spores, the oophyte part developing directly from the sporangium, or

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* This word is just a name, the meaning of which has no botanical application.

† The spore bearing stage or segment in a life cycle. Compare with oophyte (page 79).

from the surface of the sporophyte, without the intervention of the spore.

Example.—Some Ferns.

Some Special Features in Flowering Plants.

1. *Cross-Pollination* or *Cross-Fertilisation.*—The *first* term means the dusting of the stigma of one flower with the pollen from another; and the *second*, the impregnation of the ovum in one flower by the male gamete from another, the one process in Phanerogams implying the other. This is the usual method of securing fertilisation. It may be brought about by the agency of wind (*anemophilous*) blowing the pollen, which in this case must be dry, from one flower to another, or by water (*hydrophilous*) in aquatics, which produce light pollen that can be easily floated about, or by insect and other animal visitants (*zoidiophilous*), in which case the pollen is more or less sticky.

Synacmy (Homogamy).—When the two kinds of sporophyll (stamens and pistil) in a hermaphrodite flower arrive at maturity at the same time. Not common.

Dichogamy.—When the stamens and pistil in a hermaphrodite flower are not mature at the same time. There are two kinds:—*Proterandry*, when the stamens are mature first; and *Proterogyny*, when the carpels (pistil) are mature before the stamens. The former condition is the more common of the two.

Homogony (Homostyly). — When there is a uniform relationship, in respect of the height of anthers and stigma in hermaphrodite flowers belonging to individuals of the same species. The usual rule.

Heterogony (Heterostyly).—Opposite of homogony.

Example.—Primrose.

2. Cleistogamy.—Unexpanding, self-fertilised, hermaphrodite flowers are said to be cleistogamous.

Example.—Some species of Violet, &c. Not at all common.

TAXONOMY, OR THE CLASSIFICATION OF PLANTS.

Kingdom Plantæ.

Divisions.	Classes.		
I. Thallophyta.	1. Myxomycetes.		Cryptogamæ.
	2. Diatomaceæ.		
	3. Schizophyta.		
	4. Algæ.		
	5. Fungi.		
II. Archegoniatæ.	6. Hepaticæ.	Muscineæ.	
	7. Musci.		
	8. Filicineæ.	Pteridophyta or Vascular-Cryptogams.	
	9. Equisetineæ.		
	10. Lycopodineæ.		
	11. Gymnospermæ.	Spermaphyta or Phanerogamæ (Seed Producing).	
III. Angiospermæ.	12. Monocotyledones.		
	13. Dicotyledones.		

Thallophytes. — Plants whose vegetative body usually consists of a thallus (see page 54), showing no differentiation into root, stem, and leaf, or at most, rudimentary differentiation into those members. The term Thallophyta, however, should be allowed to drop, as its meaning does not apply well at all to the whole of the heterogeneous forms comprised in classes 1, 2, 3, 4, and 5, above.

Class. I.—Myxomycetes.

In the vegetative state are simply masses of naked protoplasm (*plasmodia*). When reproducing, the entire plasmodium is converted into sporangia. Their mode of life is that of the fungi.

Example.—Æthalium ("flowers of tan").

CLASS II.—DIATOMACEÆ.

Unicellular and microscopic plants distinguished by the peculiar structure of their silicified cell walls. These are composed of two halves (*valves*), one of which overlaps the other like the lid of a box. The overlapping edges are called *girdles*. Among the cell contents are plate-like chloroplastids, but the green colour of these is masked by the intimate presence of a brown pigment (*diatomin*), which makes them appear dark yellow. Diatoms exhibit a creeping movement, by which they glide over fixed bodies. They multiply by *bipartition* (see page 26), in the process of which the two valves separate, and the inner and smaller half has to be formed anew. Hence, under continuous division, as the walls do not increase to any extent, if at all, after formation, the cells gradually get smaller and smaller. A limit is, however, put upon this progressive diminution by the formation of *auxospores*, which are large

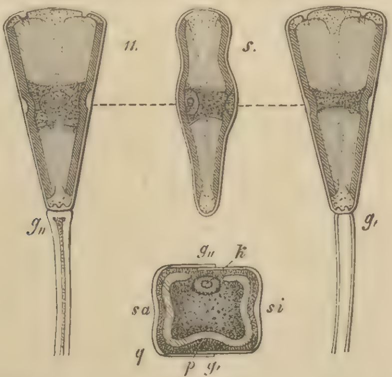

FIG. 78.—*Gomphonema constrictum* Ehrbg.; *s*, view of valves (nucleus visible); *g'*, view of the girdle corresponding to the right; *g''*, to the left margin of the valves; *q*, transverse section through the middle of the cell, showing with unusual distinctness the composition of the silicified cell-wall of two halves, one overlapping the other (*sa*, the larger, *si*, the smaller valve); *k*, the nucleus; *p*, dense protoplasm; *g'*, *g''*, the two girdle-surface. (After Pfitzer).

Life History.—1. Diatom; 2. Fission, or formation of Auxospore by rejuvenescence, or as the result of conjugation. 1. Diatom.

cells produced either by *rejuvenescence* (see page 26) after a period of growth, or by subsequent growth *after* rejuvenescence, or by *conjugation* and growth combined.*

Class III.—Schizophyta.

Very simple structure; either unicellular or multicellular, in rows or thin plates or lump-like aggregations. No cell nucleus has been found with certainty. There are *no sexual organs;* reproduction taking place by *bipartition* of isolated cells, or, where the species forms a chain of cells, these separate off into pieces, which grow up into new individuals. There are also frequently *resting cells*, *i.e.*, isolated cells that have passed into a dormant state in which they may become dried up without losing their vitality. This class is divided into two sub-classes:—

1. Cyanophyceæ which have chlorophyll. *Types*—Gleocapsa, *Nostoc*, Oscillatoria.

2. Schizomycetes which are without chlorophyll.† *Types*—Micrococcus, *Bacterium*, Bacillus, Spirillum.

Nostoc.

Moniliform rows of round cells forming a colony,‡ embedded in mucilage, mutually prepared and excreted. Single large cells, called *heterocysts*, incapable of further development, and having differently coloured watery contents, are interspersed at intervals in the chains (Fig. 79).

Occurrence.—Float in water, or lie loose on damp earth or among mosses.

The filaments increase in length by the transverse division and subsequent growth of the individual cells. New colonies are formed as follows:—1. The mucilage or jelly of the old colony softens in the water; 2. Then the parts of the filaments lying *between* the heterocysts creep out of the jelly, while the latter remain behind in it; 3. Those freed

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* Many Diatoms have also resting cells, which form a double cell wall, *i.e.*, that of the new cell inside the old.

† *Bacterium chlorinum* and *Bacillus virens* have chlorophyll.

‡ Such a colony is a cœnobium (see page 33).

pieces, now called *hormogonia*, at this stage exhibit movements, but shortly come to rest and surround themselves with a gelatinous envelope; 4. The roundish cells of the hormogonia now grow transversely and divide *longitudinally*, thus giving rise to short filaments which, remaining connected with one another at one extremity, form the commencement of a single coiled nostoc thread, certain of the cells of which become heterocysts.

Spore Formation.*—When the Nostoc dries up, several, or often all, the cells of a filament increase in size and become invested with a thick wall, their protoplasm at the same time becoming dense and of a yellow-green colour. These are spores; their exosporium (*outer* part of wall) ruptures at germination, and each spore develops a new nostoc thread.

FIG. 79.—A Nostoc Cœnobium Chain, with Heterocyst.

Life History.—1. Nostoc cœnobium; 2. Fission,† or Hormogonia, or when conditions are unfavourable, Gonidia (spores). 1. Nostoc cœnobium.

Bacterium.

Exceedingly minute, rod-like, or shortly cylindrical. Usually unicellular, but multiply by division, after which the young cells frequently remain attached and form colonies.

Occurrence.—In stagnant and putrid fluids and in diseased organisms; always appear in large numbers.

Structure of Bacterium Cell.—The protoplasm is usually colourless, and the cell wall is a kind of nitrogenous cellulose called *mycroprotein*, which is a substance apparently not far removed from protoplasm itself.

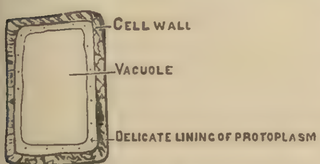

FIG 79a.—Mature Bacterium Cell.

The protoplasm contains various rather indefinite bodies, such as peculiar proteids, granules, pigments (sometimes), &c., but no nucleus

* Or rather Gonidium (propagative cell, *asexually* produced).
† Or bipartition.

has yet been discovered. The mycroprotein wall easily swells (and normally does so), forming a gelatinous exterior, or an altogether perfect jelly (Fig. 79a).

Reproduction.—Entirely asexual, by simple fission usually, but gonidia and endogonidia also regularly form in many species.

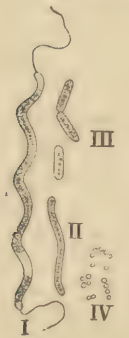

FIG. 80.—*Bacteria.*—I. *Spirillum volutans* (Ehrenberg); II. *Vibrio Rugula* (Müll); III. *Bacterium Lineola* (Cohn); IV. *Micrococcus prodigiosus* (Cohn); × 650 times. (After Cohn.)

The group of Bacteria are classified according to form or other striking characteristic. Thus round isolated cells are Coccus (Micrococcus, &c.) Straight rod forms are Bacterium (*short*), Bacillus (*long*), &c. Curved forms are Vibrio (*undulate*), Spirillum (*corkscrew*), &c. Rows of cells are Streptococcus, Leptothrix, &c. Cell masses—Sarcina, &c. Groupings of cells by *cohesion* are termed Zooglœa.

Life History.—1. Bacterium; 2. Fission, or Gonidia. 1. Bacterium.

CLASS IV.—ALGÆ.

All Thallophytes which contain chlorophyll (with the exception of Cyanophyceæ and Diatomaceæ) belong to this class. The different individuals comprised in this division are grouped together, mainly because the course of development is, though varied, essentially the same in all, the extreme forms being connected together by intermediate ones. The vegetative structure of the thallus is also very varied. The marine forms have generally mucilaginous cell-walls. There are three sub-classes:—

FIG. 81.—*Sarcina ventriculi* (Goodsir). A bacterial organism from the vomit of a dyspeptic patient. (After Behrens.)

1. Chlorophyceæ (Green Algæ).—The chlorophyll is *not* masked by another colouring matter. They all form zoogonidia,* which in some species have two cilia inserted at the tip of their pointed extremity, in others four, or a circlet of cilia at

* Or Swarm-Cells, *i.e.*, naked protoplasmic bodies moving by means of cilia.

their anterior end, or the whole surface is covered with cilia (*Vaucheria*).

Types.—Vaucheria, Pandorina, Protococcus, Pediastrum, Œdogonium, Coleochæte, Spirogyra, Closterium, Chara.

2. Phæophyceæ (Brown Algæ).—The chlorophyll is masked by a brown pigment. They produce zoogonidia, all of which have two cilia inserted near the base of their pointed extremity. They are all marine.

Types.—Laminaria, Fucus.

3. Rhodophyceæ or Florideæ (Red Algæ).—The green chlorophyll is masked by a red pigment. The male organs of fertilisation are small cells without power of *active* movement (*spermatia*). The female organ, or procarp, consists of a receptive part (*trichogyne*) and a basal part, the *carpogone* (see page 82), in which the protoplasm is not rounded off to form an ovum. Zoogonidia also occur as a rule.

Types.—Nemalion, Polysiphonia, Dudresnaya, Batrachosperum, Corallina.

Protococcus.

A unicellular, fresh-water alga, spheroidal, composed of a tough, transparent, cellulose wall, enclosing granular protoplasm, with or without vacuoles; chlorophyll, sometimes masked by red, occurs diffused or in granules. It reproduces by *fission;* by gemmation (rarely) like that of the yeast plant; by *zoogonidia*, produced by rejuvenescence or by free cell formation from a unicellular zoogonidangium (zoosporangium). The swarm-cells or zoogonidia produced in the latter case, may *conjugate* in pairs, giving rise to resting *zygospores* (see page 94).

Life History.—1. Protococcus; 2. Fission, or Zoogonidium; or Zoogonidia by conjugation, producing Zygospore. 1. Protococcus.

Pediastrum.

Consists of a cœnobium of a large number of cells, which are either arranged closely together by adhesion, without or with intercellular spaces, forming a disc. The colony is propagated by the formation in each cell of numerous zoogonidia, which issue covered over with the delicate innermost layer of the mother cell, that increases in size

together with the gonidia, which form into a disc, and elaborate mutually adherent cell walls. The mother cell layer dissolves up after the young disc has formed.

Life History.—1. Pediastrum; 2. Zoogonidia in inner lamella of mother cell. 1. Pediastrum.

Pandorina.

A hollow, spheroidal, *active*, cœnobium (each cell protrudes two long cilia through the cell walls, beyond the common gelatinous envelope of the colony), composed of sixteen closely packed cells.

Reproduction.—1. Asexual. *Each* of the sixteen cells of the old colony divides up into sixteen smaller cells (from the first remaining in union), which are set free, invested in an envelope formed from the wall of the mother cell by the solution of the gelatinous covering of the cœnobium. 2. Sexual, begins in the same way, but the young cells become quite free. They vary much in size, are rounded and green at the posterior, and narrow and clear with a red corpuscle * at the anterior end, where the two cilia are situated. Pairs of these swarm-cells (often from different cœnobia) meet at their pointed extremities and coalesce, forming an hour glass shaped body, that gradually contracts into a sphere, and elaborates a cell wall.

This product, the zygospore, by germination after a longer or shorter period of rest, protrudes and forms two or three large zoospores which escape, and, by and by, each of these after becoming surrounded by a gelatinous envelope, divides up into sixteen cells, which grow together and form a cœnobium.

Life History.—1. Pandorina; 2. Zoogonidia cells in union; or Zoospore produced from Zygospore, formed by conjugation. 1. Pandorina.

Vaucheria.

Occurs in water and on damp soil. Its thallus is green, *non-septate*,† filamentous, and branched, with a *fixed*, hyaline, and contortedly branched rooting end or part. The cell

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* A chromoplast (see page 14).

† With many nuclei, as the rule is in elongated, living, non-septate cells.

wall is thin and internally invested with a layer of protoplasm, rich in chloroplasts and oil-drops,* and enclosing a large vacuole.

Reproduction.—1. Asexual. By formation of brood-cells (gonidia); by simple abstriction of the ends of certain twigs; or of zoogonidia by rejuvenescence, as follows:—The contents of the end of a branch, which has swollen to a somewhat oval form, are partitioned off behind by a transverse wall, and then contract and force their way out as a swarm-cell at the end of the branch, which ruptures to let it pass. A membrane is excreted on the surface of this zoogonidium while in a motile state, and in about a day after it germinates.

Vaucheria may also, when conditions are favourable, pass through a resting stage (*gongrosiroid state*). The filamentous thallus becomes septate by the formation of a number of thick gelatinous cross-walls. After the period of rest has passed, when circumstances are again favourable for a more vigorous existence, each septate cell either develops into a vaucheria-filament, or their protoplasm divides up into a number of distinct portions, which come out of the mother cell in a body, collectively enveloped in a thin coating of mucilage that, shortly dissolving in the water, or becoming broken up, sets free the separate cells, which creep about like amœbæ. Each amœbiform body eventually rounds itself off, becomes invested in a wall, and either germinates directly into a vaucheria-tube or may again enter upon a period of rest.

2. Sexual. Vaucheria is *monœcious*, and the two kinds of sexual organs occur usually close together. The *antheridium*, or male sexual organ, *is the terminal cell* of a slender branch of the thallus. It is quite full of protoplasm which, however, has few chloroplasts. This protoplasm divides up into spermatozoids,† that escape at the proper time by the rupturing or disorganising of the apical wall of the cell. The female organ, or *oogonium*, is a thicker protuberance, densely filled with protoplasm, containing much oil and chloroplasts, and separated off into a distinct cell by a partition formed at, or near, its junction with the main

* The ultimate production of carbon assimilation in this case.
† Male ciliated motile gamete.

portion of the thallus. The coarse-grained protoplasmic mass collects in the centre of this organ, while a colourless protoplasm gathers at its apex where the oogonium opens.

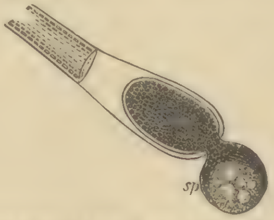

FIG. 82.—*Vaucheria sessilis* (× 30); *sp*, a newly formed zoogonidium.

The moment this occurs the whole contents contract, forming one oosphere or ovum, and (usually) a colourless slime * is expelled from the aperture. The spermatozoids,

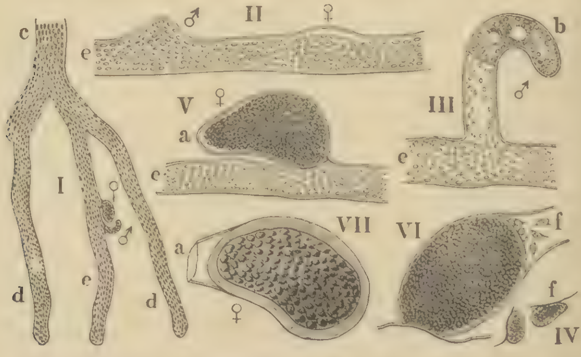

FIG. 83.—*Sexual reproduction in a Vaucheria.*—I. End of a branched cell; *d d c* Branches; and the sexual organs; II. Part of a filament showing the origin of the sexual organs; III. A young antheridium; IV. Two spermatozoids; V. Unfertilised oogonium; VI. The same at the moment of fertilisation; VII. The embryonic vesicle after being detached from the parent plant. I. × 100 times; II., III., V., VI., VII., × 600 times; IV. × 1000 times. (After Behrens.)

set free about the same time as this happens from the neighbouring male, now enter, and, fusing with, impregnate

* The *polar vesicle.*

or fertilise * the ovum, which subsequently invests itself in a thick wall; its contents becoming reddish or brown. After a period of rest, the oospore (fertilised ovum), set free from the parent, germinates, forming a vaucheria-filament, which usually multiplies itself by zoogonidia for several generations before producing sexual organs.

Life History.—1. Vaucheria; 2. Zoogonidium, or more rarely, gonidium by fission; or Amœbiform Gonidia from Gongrosira; or Ovum fertilised by Spermatozoids.† 1. Vaucheria.

Œdogonium.

Thallus of unbranched septate filaments, the cells of which increase in size by intercalary growth, which begins with the formation of an annular cushion of cellulose, close beneath the upper transverse wall of the cell that is going to elongate. The cell wall parts at this spot all round, and the internal band of cellulose stretches and becomes fixed. This process is repeated always close beneath the older upper part of the cell.

Reproduction.—1. Asexual. Zoogonidia are formed by rejuvenescence. These after a time settle down, form a cell wall, and give rise to the Œdogonium-filament by growth and division.

2. Sexual. The filaments are either monœcious or diœcious. Certain cells swell out into a more or less spherical form. Those are oogonia. Each forms, by the rounding off of its protoplasm, an ovum, the granular and hyaline parts of which separate as in Vaucheria. The oogonium opens either by irregular rupture or by an oval aperture, through which the polar vesicle, or hyaline portion of the ovum, protrudes to receive the spermatozoid.

The antheridia are certain cells of the filament shorter and less rich in chlorophyll than the vegetative cells. As a rule, every antheridial cell divides into two similar cells, each of which produces a spermatozoid, which escapes by the rupture of the wall of the mother-cell. The fertilised

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* Fertilisation.—The result of the sexual act when the gametes are dissimilar.

† Or Zygote, *i.e.*, a general term for the product of coalescence of two gametes.

ovum, or oospore, after separation and formation of a wall, rests for a considerable time, and then gives birth to zoospores, which, after a short period of swarming, come to rest and develop into the vegetative thallus. In some diœcious species the cells of the filament may form peculiar zoosperms,* which adhere to the oogonium and grow into dwarf males, which are unicellular. Each dwarf male naturally develops two sperms.

Life History.—1. Œdogonium; 2. Zoogonidium; or Zoospores produced from fertilised ovum. 1. Œdogonium.

Coleochæte.

A small, fresh-water alga, composed of branched rows of cells, and fixed to a submerged part of some larger aquatic. Certain cells of the thallus form lateral colourless bristles which are enclosed in narrow sheaths.

Reproduction.—1. Asexual. A zoogonidium forms by rejuvenesence and develops into an asexual plant, which, after a series of generations, becomes monœcious or diœcious, according to the species.

2. Sexual. The female organs are unicellular. They form at the ends of the branches and acquire a flask shape, with a long neck (*trichogyne*), open at the top, out of which a colourless mucilage (polar vesicle), formed from the single ovum within, is ejected at time of fertilisation. Antheridia are formed by the outgrowth in adjacent cells of two or three protuberances from each, which are separated off by transverse walls. Each protuberant cell, which also acquires a flask form, without the long neck, is an antheridium, and its entire contents form a spermatozoid with two cilia.

As the result of fertilisation, the oospore forms a cell wall of its own, increases in size, and becomes surrounded with a cortical layer of cells, produced by the upward growth of branches from the supporting cell of the old plant, and then rests throughout the following winter. In spring, the oospore, by repeated bipartition, forms a parenchymatous tissue, within each cell of which a zoospore arises, which,

* Or Androspores.

escaping when the cortical layer falls off, gives rise as in (1.) to a fixed asexual plant, that again in due course becomes sexual, and so on.

Life History.—1. Coleochæte; 2. Zoogonidium by rejuvenescence; or Zoospore arising as result of fertilisation. 1. Coleochæte.

Spirogyra.

The vegetative filamentous thallus is green, free living *septate*, and unbranched, found floating on fresh water of ponds and springs. The chloroplasts are in the form of

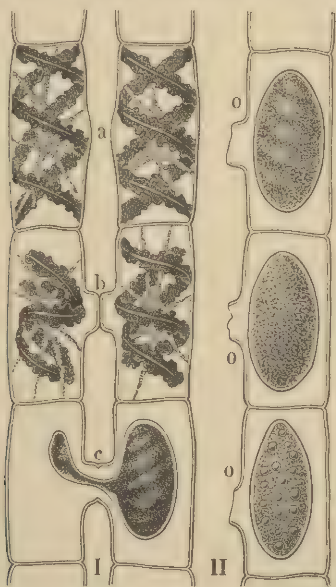

FIG. 84.—Conjugation in Spirogyra cells.—I. Two filaments ranged side by side; at *a*, Processes are beginning to form; *b*, Processes in contact; *c*, Protoplasm passing from one cell to another. II. Filament after conjugation; *o o*, Its cells in different stages; × 450 times. (After Behrens.)

spiral bands, which contain little round nuclei-like bodies known as *pyrenoids*. The starch manufactured by the chloroplast is always formed at one of these pyrenoids.

There is a relatively large cell nucleus lying near the centre of the cell, and surrounded by protoplasm, which joins the wall layer of that material across the intervening vacuole in a delicate, radiating fashion. Increase in bulk takes place in the usual way by bipartition and subsequent growth.

Reproduction.—1. By Fission; an ordinary cell being cut off, which lengthens and divides transversely; 2. Rejuvenescence (not common); 3. Sexually, by conjugation. In this process two filaments lay themselves alongside of each other, and the opposite cells put out wall projections towards one another which meet; and, by dissolution of the intervening walls at the meeting point, form narrow tubes, through which the protoplasm of the cells of one filament pass over into the protoplasm of the cells of the other filament. Previous to this translation, however, the protoplasmic contents of each cell contract to an oval mass (the gamete). The result of the act of conjugation is a rounded *Zygospore*,* which invests itself with a thick hard cuticular coat, and after a period of rest germinates and forms a new cell filament.

Life History.—1. Spirogyra; 2. Fission, or, more rarely, Rejuvenescence; or formation of Zygospore after conjugation. 1. Spirogyra.

Closterium Lunula.

Unicellular, fusiform, and crescentic in shape: contains numerous chloroplasts, with larger starch granules, arranged in four rows. The nucleus is situated at the white spot in the centre, and at either end of the organism is a colourless vesicle containing a number of minute crystals in constant vibratory motion.

FIG. 85.—A unicellular alga (*Closterium lunula*), one of the Desmidiaceæ, × 300 times. (After Behrens.)

Reproduction.—1. Asexual by simple fission; 2. Sexual by conjugation, as in Spirogyra, giving rise to a zygospore. Instead of the contents of the one cell, however, passing over bodily into the other,

* Or Zygote.

the connecting tubes swell at their opposing ends like a bladder, the end walls that separate them disappear, and the contents of each individual unite in the broad canal thus formed. The coalesced protoplasmic masses now contract into a spherical form (*zygospore*), and this becomes invested with a delicate gelatinous wall, which, as the spore ripens, thickens and becomes differentiated into three layers, the most external of which produces spinous processes. On germination, the delicate colourless inner layer presses out with the contents through the ruptured outer lamella, but this remnant of the old wall is soon replaced by a new and stouter membrane which forms inside and throws it off. The protoplasm now divides into two hemispheres, each of which in a day or two becomes like the parent, only it multiplies asexually alone for a considerable time.

Life History.—1. Closterium ; 2. Fission ; or Zygospore, from conjugation. 1. Closterium.

Ulva (Common Green Sea-Weed).

Thallus, a flat expansion of a double layer of cells, more or less branched, with rhizoids. Vegetative reproduction takes place by the detachment or isolation of cells, which produce zoogonidia, that develop into the parent form.

Chara.

This type occupies the highest place among the green Algæ, and is not very closely allied to any of them. Its structure is complex, and its sexual organs show great peculiarities of form and a very considerable amount of differentiation. The vegetative body can scarcely be considered a thallus as it is differentiated into *stem* and *leaves*, which are physiologically typical enough if morphologically rudimentary ; and from the former *rhizoids* are developed, which root the plant in the mud of the river or pond in which it grows. The main shoot, which bears the sexual

organs, has unlimited apical growth. The structure of this can be seen in Fig. 86 below—

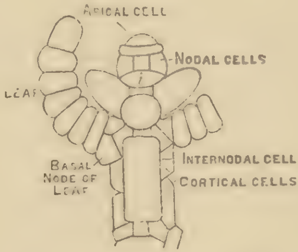

FIG. 86.—Apical Portion of Shoot of Chara.

The apical cell divides into two by transverse walls, and each segment again divides in the same manner into two cells, one lying above the other; the lower of these (*i*) does not divide again, but becomes an internodal cell, which afterwards elongates greatly; the upper scarcely grows at all, but divides by a vertical wall into two, and these go on dividing by anticlinal walls until a whorl of peripheral nodal cells are formed. From the node, the verticillate leaves are developed, one from each of the peripheral cells, and the secondary stems or branches spring from the axil of the first, or oldest leaf, of the whorl.

Each leaf begins by a basal node, and these basal nodes are the starting point for the formation of the cortex which covers the internodes of the stem. From the basal node of every leaf, distinct cortical lobe cells run, one upwards and one downwards, and these grow and divide transversely like the stem.

The rhizoids spring from the outer cells of the lower nodes of the main shoot, to which they are attached by a broad base. They are long, white, or clear cells, or cell rows, which grow obliquely downwards, and elongate only at the apex.

Reproduction.—1. Asexual. By the formation of *bulbils* (amylum stars), which are isolated subterranean nodes with much shortened leaf whorls; or by detached *branches*. 2. Sexual. The *antheridium* and *oogonium* (see pages 82, 83) are formed on the leaves, the former being the metamor-

phosed terminal cell of a leaf, or lateral leaflet, and the latter is produced close beside it from the basal node of a leaflet.

The antheridium is a round hollow body, the wall of which is made up of eight flattish cells or *shields*. From the centre of the inner concave face of each of these a sort of short process (the *manubrium*) projects into the internal cavity. At the free end of the manubrium is a rounded body, the capitulum or *head cell*, and each head cell is surmounted by six smaller cells (*secondary head cells*, or capitula), from each of which proceed four long whip-like cell-row filaments, every cell of which contains one *spermatozoid*.

The oogonium, when ready for fertilisation is ellipsoidal in form, is supported on a very short stalk (*pedicel cell*), and consists of an axile row of cells closely invested with an envelope of five spirally-twisted tubes. The pedicel cell answers to the lowest internode of a shoot, and bears a short nodal cell from which the envelope-tubes are developed like a whorl of leaves. Above this nodal cell is the large ovoid apical cell of the shoot, functioning as the *ovum*, at the base of which a short hyaline cell is divided off.

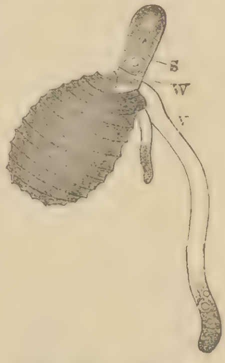

FIG. 87. — *Germinating oospores of Charæ.*—Spore with seedling plant issuing from it (*Tolypella intricata*). *s*, Cell, from which the stem develops later on; *w*, Original mother-cell of the root; *v*, Root (primary root); *p*, Spore; *k*, Anterior cell; × 90 times. (After De Bary.)

The ovum is filled with protoplasm containing oil-drops and starch grains, but in its apical region (*apical papilla*) the protoplasm is hyaline.

The envelope tubular cells are divided off at the apex into five small cells, which form the *neck* or *crown*, and close in the cavity in which the ovum lies.

At the time of fertilisation, five lateral fissures appear between the neck cells, and through these the spermatozoids find their way to the ovum through the neck entrance and interior, which is filled with mucilage. After fertilisation the oospore elaborates a cellulose wall, the envelope becomes

hardened and dark, and the whole falls to the ground and rests till the germinal period, when the oospore forms a *nodal cell* at its apex, the lower portion, or *basal cell*, acting as an organ of reserve food stuffs. From the former, the further development of the embryo proceeds. It divides by a vertical septum into two daughter cells, each of which gives rise to a tubular row of cells. One of these is the so-called *primary root*, the other, the *proembryo*, which develops first a rhizoid and then a stem-forming node.

Life History.— 1. Chara ; 2. Bulbil, or detached Branch ; or germinating Oospore (produced by fertilisation), which gives rise to a Proembryo. 1. Chara.

Laminaria (Tangle).

The thallus has a stem, or *stalk*, of greater or less length, with *root-like organs* of attachment at the base, and a widely spread, flat, divided, or undivided, *lamina* at the top. The stem increases in thickness by a secondary meristem, which forms beneath the rind, in which are also gum passages similar in structure to those in the Cycadeæ. The stem anatomy is practically the same as that of Fucus (see below), consisting of a central medulla and a peripheral portion, the cells of which form filiform prolongations that grow in between the cells of the medulla. The growing point of the stem is intercalary, and is situated at the part where it passes into the lamina, the latter being usually thrown off every year. The only properly known organs of propagation are *unilocular gonidangia*, which are roundish dark-coloured sacs occurring in rows on the lamina, and these produce *zoogonidia*.

Fucus (Bladder Wrack).

Dichotomously branched thallus with root-like attachments. The branching appears to be all in one plane. A cross section shows the thallus to consist of a parenchymatous cortex and a medulla, into which the innermost layers of the former produce long filiform outgrowths. The cells of the cortex are, for a longer period, more capable of dividing than those of the medulla, and secondary growth

in thickness occurs, as in Laminaria, by (1) cell-divisions in the outside cortical layer; and (2) by the inner cortex formation growing out into new filaments (or hyphæ), which penetrate equally in between the pre-existing outgrowths in the medulla, and push the whole circumferentially apart. Portions of the tissue frequently separate from one another in the interior of the thallus, especially in the upper parts, and thus give rise to air cavities, which, latterly projecting as bladders on the exterior, serve as "floaters." No asexual organs of reproduction.

The *antheridia* and *oogonia* are formed in globular cavities (*conceptacles*),* which appear crowded together at the ends of some of the branches. The conceptacles may either be hermaphrodite or diœcious (unisexual). The antheridia appear in great numbers on the branched filaments which spring from the cells that line the conceptacle. Each antheridium is a single oval cell, whose protoplasm divides up into a vast number of spermatozoids, which contain a red spot, are pointed at one end, and move about by the help of two cilia.

The oogonium is a round body on a short stalk cell. The round upper part is at first one large cell, which, later on, divides up endogenously so as to form in its interior eight ova, and acquires for strength a two layered wall. *Fertilisation* takes place outside the conceptacle. The outer wall of the oogonium ruptures, and the ova come out enclosed in the inner delicate layer, which, becoming dissolved, sets the naked ova free. The spermatozoids are liberated about the same time, *when the tide is low*, and when the tide comes up it washes the ova and the spermatozoids among each other. The former, being specifically heavier than the water, slowly sink, and the sperms also turn from the light rapidly and go down on to the eggs, which they fertilise. The oospore now becomes invested with a wall, attaches itself to some object, and begins to germinate at once by elongating, and then dividing by a cross wall into a small basal and a larger upper cell. The former dividing up

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* The conceptacula arise as depressions on the surface, which subsequently get so grown over by the surrounding tissue that, at last, only a narrow round opening remains to the outside.

gives rise to the root, and the latter to the thallus. No alternation of generations known.

Life History.—1. Fucus; 2. Oospore. 1. Fucus.

Polysiphonia (Common Red Sea-Weed).

The thallus is filamentous, and very much branched, with a small root-like anchoring disc. On the whole, its appearance resembles a delicate and highly ramified (dichotomously) typical shoot. It is commonly epiphytic in habit (but not a parasite), often anchoring itself on another and stronger plant by its root.

With regard to structure, two sets of cells can be distinguished—a *central* row surrounded by a peripheral (*pericentral*), or cortical set. The continuity of the protoplasm from cell to cell can be well made out in this plant.

Asexual reproduction is effected by non-motile gonidia, called *tetragonidia*, because four are formed in one mother-cell or gonidangium. The latter is formed just like any of the other cortical cells, by the division of a young central cell. The gonidia escape by the rupture of the mother wall, and by germination give rise to new plants, which are like the parent, but usually sexual.

The *sexual* organs generally occur on plants (which are either monœcious or diœcious) that do not form gonidia. The *Spermagonium* (or male organ producing non-motile* gametes—compare with antheridium) is produced on the end of a growing branch. It begins, of course, as a single cell, which grows and divides until an elongated cone-like body is formed, consisting of a central axis of jointed cells (borne on a unicellular stalk) which are surrounded by a peripheral layer of closely arranged cells, that subsequently round off and develop spermatia—one in each cell. When ripe, the walls of the mother-cells (*spermatic cells*, or spermatocytes) rupture; and the spermatia, which are round solid nucleated balls of protoplasm, get into the surrounding water.

The female organ, or *procarp*, is developed towards the apex of the plant from the terminal cell of a lateral branch.

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* Or, passively, motile gametes which are called spermatia.

The terminal cell is the *archecarp* (enclosing the ovum), and a hair-like delicately walled process, also filled with protoplasm, to which it gives rise near its apex, is the *trichogyne.*

Fertilisation.—The spermatia, floating passively about in the water, come in contact with the rounded head of the trichogyne, and *conjugate* with the contents of the latter. The fused contents are then withdrawn into the archecarp below, and thus *fertilisation* is indirectly effected.* The trichogyne now begins to wither away; and the ovum, in the enlarging archecarp (carpogone) becomes pluricellular and develops close-set, branching, and radiating cell-rows, the end cells of which are spores † (carpospores) that escape, when ripe, through the ruptured apex of the capsule. This spore producing fructification is called a *sporocarp*, and it represents the sporophyte of higher plants. The spore germinates at once, forming first a clear basal cell, which develops into the root, and an apical coloured cell, which gives rise to the thallus.

Life History.—1. Polysiphonia; 2. Tetragonidium; or Spore produced in a sporocarp as the result of fertilisation. 1. Polysiphonia.

Nemalion.

This is a simple form of monœcious Red Sea-Weed, in which the fertilised archecarp divides up bodily into a mass of spores, no capsule being made to enclose them.

Class V.—Fungi.

Have no chlorophyll, in consequence of which they are dependent for their food on the organised substances of other plants or of animals, that is to say, they are either *parasites*, when they absorb the nutritive matter of living

* The fusion takes place through the wall, the trichogyne remaining perfectly closed.

† These are therefore spores produced into the cavity of the sporocarp by budding from a cushion of cells.

beings, or *saprophytes*,* when they obtain it from the remains of dead organisms or from organic compounds formed by living organisms.† The thallus is usually composed of filiform, unicellular or multicellular, branching tubes or *hyphæ* ‡ (in the simplest forms, however, the vegetative body does not acquire the hyphal structure). The hyphæ, which spread in the substratum as organs for absorbing food form the *mycelium*, and correspond as far as general function goes to simple absorbing roots or rhizoids. The special branches of the hyphæ, which usually rise above the mycelium and serve for reproduction, that is, produce the spores, are called *carpophores* or fructifications. ||

The Fungi are most abundantly propagated by motile or non-motile gonidia, the most prevailing mode of formation of the latter being by abjunction.

Classification.—There are six sub-classes :—

1. Chytridicæ.—Simplest Fungi. Reproduction by means of zoogonidia, which usually possess but one cilium. Many species have resting cells. Sexual process *very rare*. *Types.*—Chytridium, Protomyces.

2. Ustilagineæ.—Live inside land-plants. All form resting cells. This group is collectively known, from the pathological appearances produced by them, as the Smut or Bunt-fungi. *Types.*—Entyloma, Ustilago, Tilletia.

3. Phycomycetes.—Mycelium greatly branched, and non-septate, at least during the earlier period of growth, if not throughout life. *Types.*—Mucor, Pythium, Saprolegnia.

4. Ascomycetes.—Very complex structure. Mainly distinguished by producing their gonidia in *asci*, that is, club-

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* But one and the same Fungus *may* live in both ways, *e.g.*, Pythium de Baryanum.

† Fungi must get their carbon in the form of ready prepared carbohydrate or other suitable *organic* compound, but they can generally make use of *inorganic* matter for the other essential food constituents, as nitrogen, which they can take from ammonia or nitrates.

‡ Forms with elongated non-septate hyphæ have, of course, numerous nuclei.

|| Carpophore is the same as sporophore or sporophyte.

shaped tubes or globular sacs at extremities of hyphal branches, within which gonidia (typically eight) are developed. *Types.* — Podosphæra, Eurotium, Penicillium, Xylaria, Claviceps, Peziza, Ascobolus, Tuber, Saccharomyces.

4A. Lichens.—These are genuine Fungi of the division of the Ascomycetes (with the exception of a few genera that belong to the Basidiomycetes), living in *symbiotic* union as a kind of parasites on, and with, Algæ, belonging to a variety of groups (generally Chroococcaceæ and Palmellaceæ). The tissue of the Fungus, as a rule, grows so copiously around and among the cells of these Algæ, that the latter at length appear to be merely scattered through the compact hyphal threads, or to form a distinct layer (the *gonidial layer*) in the mass. *Types.*—Collema, Usnea, Parmelia.

5. Uredineæ.—Found exclusively in living Phanerogams. Have the same course of development as Ascomycetes. Their usual fructification is known as an *æcidium*, which, when mature, consists of a cup-shaped envelope (*peridium*) and a *hymenium*,* occupying the bottom of the cup from the basidia † of which spores (æcidiospores) are successively obtained by abstriction. Besides these, special gonidial forms usually develop. *Types.*—Puccinia, Endophyllum.

6. Basidiomycetes.—Comprise the largest and handsomest Fungi. The spores are borne singly or in groups (usually of four) on basidia, which together form the hymenium. Each basidium usually bears at its summit four small slender stalks, or *sterigmata*, from each of which a spore is abjointed. *Types.*—Agaricus, Phallus.

Protomyces.

Parasitic on the shoots of Umbelliferæ. Mycelium of septate filaments. Single cells of this swell up and form tough walled resting spores, which germinate in the follow-

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* A stratum of spore mother-cells (basidia).

† Mother-cells from which spores are acrogenously (one after the other from the top) abjointed.

ing spring by protrusion of the inner cell wall, the contents of which break up into rod-like spores (gametes) that, when set free, conjugate in pairs. A germ tube sprouts from one of the two united spores, forces its way into the plant host, and there produces a mycelium, which again gives rise to resting spores.

Life History.—1. Protomyces; 2. Resting Spore producing Gametes, which Conjugate and generate a Germ tube. 1. Protomyces.

Entyloma.

Parasites in intercellular spaces of leaves of Buttercup, &c. Mycelium of clear, slender, delicately septate hyphæ, single cells in which swell up and become resting spores, that on germination put out a short blunt germ tube of limited growth, the *promycelium*. At the apex of this a whorl of slender pointed branches (*sporidia*) arise, which conjugate in pairs by means of a lateral protuberance. From the conjugated sporidia a germ-tube is produced, which bores into the host, or it gives off from its end, by abstriction, a *secondary* sporidium, that forms a penetrating germ-tube.

Life History.—1. Entyloma; 2. Resting Spore, which forms a promycelium with sporidia that conjugate in pairs, from each of which a penetrating Germ-tube is produced direct, or from secondary sporidium. 1. Entyloma.

Mucor.

This Fungus is saprophytic in its habit, living on fruits, bread, dung, &c.

Mycelium.—Much branched, non-septate, with numerous small nuclei imbedded in the protoplasm.

Reproduction.—1. Asexual. Thick filaments grow up from the mycelium, rise erect into the air, and ultimately swell into globular heads or cells at their extremities (Fig. 88). By the division of the contents of each of those terminal cells or gonidangia (of course partitioned off from the rest of the plant), numerous gonidia are produced,* after which the

* These single stalk-like hyphæ (or compound hyphæ), in or on which gonidia are formed, are known as *gonidiophores* (see Fig. 88).

filament portion grows up for a small distance into the cavity of the gonidangium (see Fig. 89), by the bursting of the wall of which the gonidia are finally set free, and these falling around the parent germinate at once, producing mycelia.

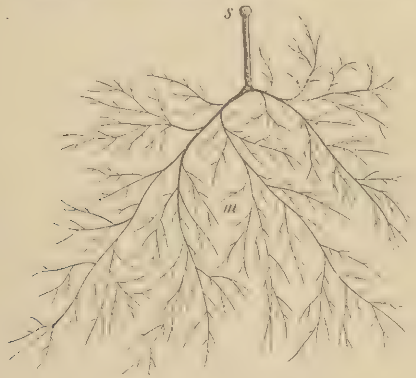

FIG. 88.—*Mucor Mucedo, m;* Mycelium bearing a Gonidangium, *s.* (After Prantl.)

The mother mycelium portion itself sometimes produces *gemmæ* by the division of its tubular filaments by cross septa, into short members or cells, which round themselves off, and give rise, when circumstances are favourable, to new

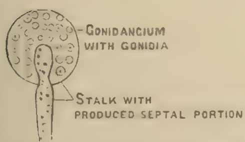

FIG. 89.—Gonidiophore, or Stalked Bud-sac of Mucor.

FIG. 90.—Conjugating Branches of Mucor Mycelium.

mycelia. Those latter gonidia are commonly known as Mucor-yeast, from their resemblance to ordinary yeast (see Fig. 52) in the process of multiplication by budding, and in the generation of fermentation in a suitable liquid. The 'mucor-yeast' gonidia are only produced in certain abnormal

cases, as when the parent is quite submerged in a fluid (and so unable to send up ærial filaments) instead of growing at, or quite near, the surface, as it usually does.

2. Sexual (rare in common mucor), by conjugation as follows:—Buds grow out from neighbouring hyphal branches of the mycelium and meet (Fig. 90). The end walls of the outgrowths then break down and the contents fuse. Previous to this, however, the end portions of the outgrowths become partitioned off from the rest of the mycelium. The single cell now formed by conjugation is a zygospore* (Fig. 91). It rounds off, grows very much bigger, and finally elaborates a very thick wall for its protection, after which it rests for a time. When favourable conditions recur, each zygospore bursts its cuticular or external portion of the wall, and grows out directly into a new mycelium, or, more rarely, into a stalked sporangium (like the gonidangium), from the spores of which new mycelia are produced.

FIG. 91.—Zygospore (*z*) of Mucor. (After Prantl.)

Life History.— 1. Mucor; 2. Gonidium; or Zygospore producing mycelium directly, or Spore which does so. 1. Mucor.

Pythium de Baryanum.

Thrives equally well as a saprophyte or parasite. Its mycelium is non-septate.

Reproduction.— 1. Asexual. At the beginning of its mature existence, propagation is effected almost entirely by gonidia or zoogonidia, which are produced in gonidangia that are either intercalary or terminal on the mycelium.

The gonidangium arises as a swelling, which, after the greater part of the protoplasm of the filament producing it has passed into it, becomes separated from the latter by a partition. The contents of this unicellular bud-sac now break up into either gonidia or zoogonidia,* which escape

* Or unicellular Zygote.

† Generally zoogonidia, each of which has two cilia.

by the solution or breaking up of the mother wall. The motile buds germinate shortly, and give rise to the adult structure; but the gonidia are resting forms that persist after the mycelium has died away, and develop germ-tubes* on germination.

2. Sexual. A portion of a branch (usually the extremity) of the mycelium swells up into a globular form, and the neighbouring protoplasm moves into this, which becomes the *oogonium* (see page 83) when cut of by a transverse partition (Fig. 92). Near the oogonium, the *pollinodium* develops as a lateral short branch-like protuberance that in growing curves in the direction of the former. When its extremity† gets in contact with the oogonium, it (having by this time become a distinct cell by the formation of a cross wall) develops a narrow *fertilisation tube* that penetrates the wall of the female, passing through the peripheral protoplasm (*periplasm*) to the central rounded off part or ovum into which it pours its *gonoplasm* (central protoplasm) that impregnates or coalesces with it. When the passage of the latter begins, the more granular protoplasm of the ovum retires from the point of contact with the fertilisation tube, leaving a narrow clear spot (*receptive spot*), in front free. The particles of the gonoplasm move slowly into the substance of this spot, and then in towards the dark granular portion, and disappear in it.

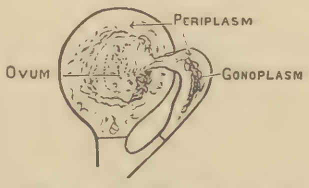

FIG. 92. — Fertilisation of Pythium. Oogonium (with ovum), and Pollinodium.

After fertilisation, the ovum becomes invested with a thick cellulose wall, and it can now go through a resting stage. By subsequent germination it either gives rise to a mycelium at once, or breaks up into *zoospores* which produce mycelia.

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* Germ-tube is the tube of the inner layer of the wall of gonidium or spore put out in germination.

† When the fertilisation-tube begins to grow, the protoplasm of the pollinodium becomes separated into a thin layer (periplasm) which lines the wall, and a central larger part (gonoplasm).

Life History. — 1. Pythium; 2. Zoogonidium, or Gonidium: or fertilised Ovum. 1. Pythium.

Eurotium (Blue Mould).

Lives in decomposing organic substances. Mycelium septate. From this, gonidiophores rise in great numbers. These swell into a round form at their upper extremities, and from the heads arise numerous conical projections (*sterigmata*) radially disposed. Each sterigma gradually gives rise, by abstriction,* to a long row of greenish gonidia, during the production of which sexual organs are being formed on the same mycelium.

The female is a *screw-like archecarp*, produced at the extremity of a branch of the mycelium. As it develops, its spirals approach nearer and nearer to each other, until they give rise to a hollow screw. While thus progressing, about as many delicate cross walls (five or six) appear in the coils as they make turns in the screw.

From opposite sides of the lowest turn of the archecarp, two slender branches now grow up outside that body, and, one of these growing faster than the other, gets up to the uppermost closed in turn, and applies its apex to it. This more energetic branch (divided off as usual) is the *pollinodium*, and conjugation takes place between its apex and the apex of the archecarp, the *intervening* wall portions dissolving.

After this act of *fertilisation*, new branches shoot out from the base of the pollinodium filament, and also of the archecarp, and they increase in number until the latter is entirely covered over by them (Fig. 93, *C*). Then a layer of polygonal cells is formed out of those closely-applied filaments by cross divisions and irregular growth, and this constitutes the *envelope* of the archecarp (Fig. 93, *D* and *E*). The cells of the envelope afterwards grow out, and divide on their *inner* side, until an internal pseudo-parenchyma (*filling tissue*) fills up the whole inner space and the turns of screw, which have now become slightly apart by growth (Fig. 93, *F*). While this development has been proceeding, numerous transverse walls have formed in the archecarp, and a number of walled branches have grown out from its cells in every direction between those of the filling tissue. The terminal

* And therefore the development of the gonidia is basipetal.

cells on these ramifications are the *asci*,* during the further development of which the filling tissue becomes looser, its

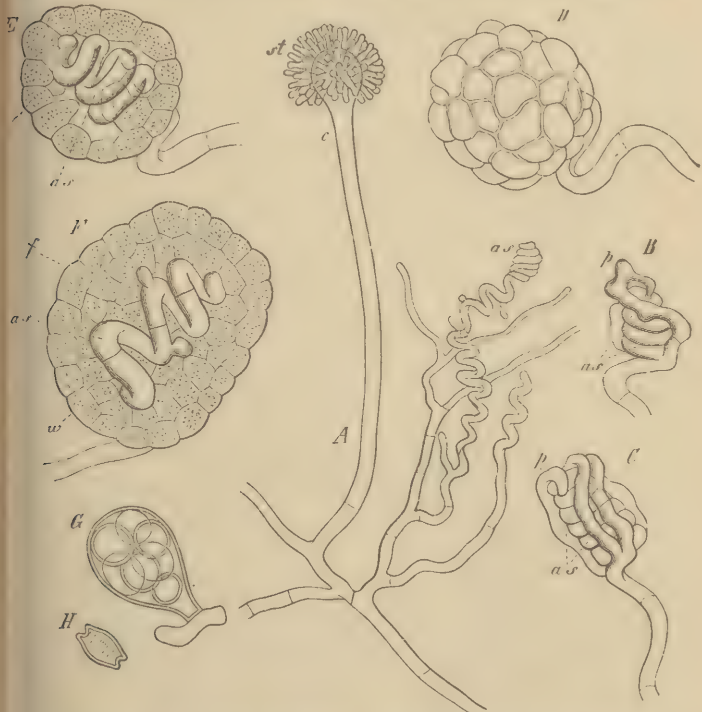

FIG. 93.—*Eurotium repens.* *A*, Part of mycelium with gonidiophore (*c*); *st*, sterigmata from which gonidia have fallen off; *as*, young archecarps. *B*, Spiral archecarp *as*, with pollinodium branch *p*. *C*, Same, with filaments growing up over it after fertilisation. *D*, Cleistocarp or fructification seen from the outside. *E*, *F*, Young cleistocarps in longitudinal section; *w*, parietal cells; *f*, filling tissue; *as*, archecarp. *G*, Ascus. *H*, Ascospore. (After Prantl.)

cells lose their nutriment, and finally disappear, their place being taken by the *eight-spored asci* (Fig. 93, *G*, *H*).

* Which are just sporangia.

By the drying up of the envelope layer, and the breaking down of the asci walls, the spores are set free and germinate in the usual way by the rupture of the *exosporium* (or outer wall) and the growth and protrusion of the *endosporium* (inner wall) into a germ tube from which the mycelium is developed. The mycelia produced from the spores, like that which originates from the gonidia, gives rise first to gonidiophores (sporophores), and then to *cleistocarps.* (The name of the whole closed structure in which the asci are formed is cleistocarp, which is equivalent to sporocarp, and represent the sporophyte generation of higher plants.) The alternation of generations is not at all distinct.

Life History.—1. Eurotium. 2. Gonidia; or Ascospores. 1. Eurotium.

Peziza.

One form is familiar as scarlet cups on trees. These are, of course, the sporophore portions which bear the asci.

FIG. 94.—(*a*) *Peziza virginea* on a dry beach twig; nat. size. (After Behrens.)

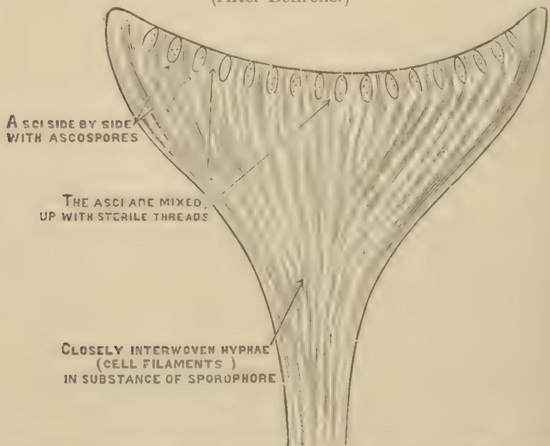

FIG. 95.—Vertical section of Sporophore of Peziza. (For a small portion of the upper part of the above diagram greatly magnified, see Fig. 68).

Reproduction.—1. Asexual by gonidia, which form from filaments of mycelium.—2. Sexual (usual). The female (*archecarp*) and male (*pollinodium*) form on extremities of ramifications of ascending hyphæ. After fertilisation, the archecarp is invested with numerous ascending filaments (see Eurotium). This tissue constitutes the body of the fructification, on the upper side of which closely-crowded hyphæ immediately arise to form the hymenial layer, and finally the familiar Peziza cup is fashioned, which produces ascospores in its hymenium (see Figs. 68, 95).

Life History.—1. Peziza; 2. Gonidia (not common?); or Ascospores. 1. Peziza.

Claviceps (Ergot).

Parasitic on the grain of Grasses. Its growth and life cycle begins as a filamentous *septate mycelium*, resulting from the germination of an ascospore on the young ovary of Rye or some related grass. The mycelium developed from the germ-tube covers the surface of the ovary with a thick felt, and penetrates into the greater portion of its tissue.* In this way a soft white mycelium takes the place of the ovary and roughly retains its shape. The surface of this hyphal tissue forms innumerable *gonidia*, which are radially disposed on *basidia*, and they drop out from between the envelopes of the flower embedded in sweetish mucilaginous matter. In this condition, Claviceps used to be known as *Sphacelia* or Honey-dew. The gonidia are carried about in their slime by insects, and may germinate at once and spread sphacelia in neighbouring flowers.

During the abundant formation of gonidia, the mycelium forms at the base of the ovary a thick zone of more compact hyphæ, which is the beginning of the *sclerotium* or ergot stage, and its outer surface turns dark violet, while it develops into a horn-shaped body, often an inch in length. The sphacelia now ceases to grow, and dries up, being finally pushed off at the apex of the ovary by the actively spreading sclerotium that soon pervades the whole grain, which then really becomes nothing but a mature and hard mass of

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* Usually sparing the apex, and frequently other parts.

sclerotium. This now rests till the autumn or spring, when the sclerotium body, if it lies on moist ground, develops the fructifications in the shape of several *stromata*, which are little knob-like bodies borne on stalks. For the structure and parts of a stroma see Fig. 96 below. It arises from the interior by the formation of numerous crowded and tufted branches * at certain spots on the central hyphæ, and these tufts burst the outer wall and develop into the ærial stroma.

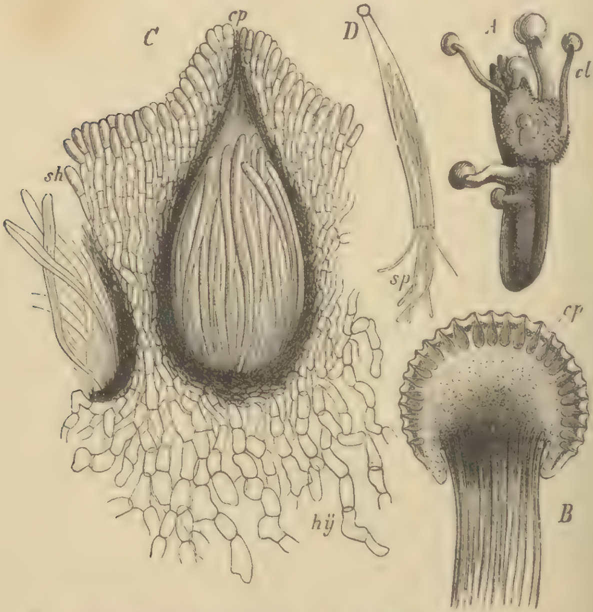

FIG. 96.—*Claviceps purpurea*. *A*, a Sclerotium (× 2), bearing Stromata (*cl*). *B*, Section of a Stroma; *cp*, Peripheral layer of Sporocarps (cleistocarps), each opening on a Papilla. *C*, a Sporocarp, with its asci and surrounding tissue highly magnified; *cp*, its opening; *hy*, hyphæ of the head of the stroma. *D*, Ascus ruptured at apex and discharging its spores. (After Prantl.)

Note that the sporocarp is apparently *apogamously*

* Or mycelial hairs.

developed (see page 98), and that there are two distinct conditions of development—1. Purely *parasitic* (sphacelia); 2. *Not* parasitic when formed, but absorbing inorganic nourishment and water, and using up its reserves while developing stromata (sclerotium). This alternation of parasitic with non-parasitic existence, or desertion of host, is termed *lipoxeny*. Compare with *autoxeny* (going through all stages of life cycle on the same host), and *metoxeny* (change of host—see Puccinia).

Life History.—1. Sphacelia condition of Claviceps; 2. Gonidium; or Ascospore *apogamously* developed in ascus in sporocarp of Sclerotium. 1. Sphacelia.

Saccharomyces (Yeast).

A *saprophyte*, distinguished by the power of exciting alcoholic *fermentation* in sugary fluids. *Usually unicellular*, but often forms, by successive budding, a kind of thallus of sprouting oval cells (see Fig. 52, page 71), which, however, separate easily. These mature cells consist of a delicate cell wall and vacuolated protoplasm in which no nucleus has yet been observed.

Reproduction.—Asexual, by budding, the daughter cell, either separating at once from the mother by constriction, or continuing united to it for sometime; if the latter happens while many generations of daughter cells are produced, the result is a *sprout chain* or temporary thallus.* If yeast cells be cultivated on a slice of potato, turnip, &c., single cells are changed into *asci*, in which from two to four (instead of eight) *ascospores* are formed (degeneration of the type of ascomycete), which can germinate at once, producing yeast-sprout, or *retain* the power of germination for a considerable time.

The greater part of the sugar of the solution during fermentation, by the action of yeast, is resolved into CO_2 and alcohol, but a small portion breaks up into glycerine and succinic acid, and the remainder, about one per cent., is assimilated by the plant. There must also be some nitrogen in the liquid, combined as an ammonium salt, or as a nitrate, or as a soluble organic substance. The

* This mode of multiplication is very rapid.

yeast plant can live in saccharine solutions that contain no ærial or ordinary free oxygen, when fermentation is active, getting all it requires for respiration from the sugar, which it decomposes. Oxidation by free atmospheric oxygen is, however, eminently favourable to its fermentative activity and growth.

Life History.—1. Yeast plant ; 2. Bud-cell ; or Ascospore *apogamously* developed. 1. Yeast plant.

Collema Crispum (Jelly Lichen).

The *vegetative thallus* is a flattish, irregular, dark, lobed, gelatinous body with *rhizoids*, which proceed from the outer cells of the under surface. These outer cells form a regular

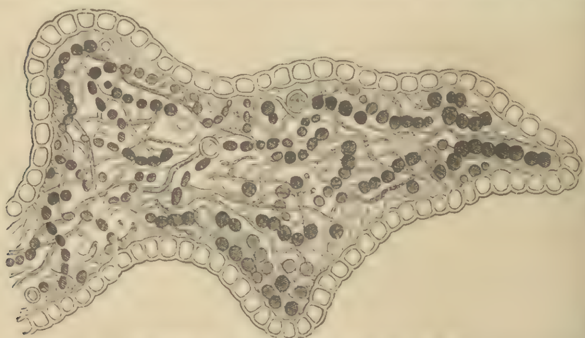

FIG. 97.—*Leptogium scotinum*, vertical section of the gelatinous Thallus (× 550) ; an epidermal layer clothes the inner tissue, which consists for the most part of formless and colourless jelly, in which the coiled strings of Gonidia lie ; single larger cells of the strings (the lining cells) are of a lighter colour ; between them run the slender Hyphæ. (After Goebel.)

bounding *epidermis* with common walls, and within this the substance of the thallus consists of the, more or less, closely interwoven hyphæ of a *fungus* of the ascomycete type, in the interstices of which occur (in this case *uniformly* and equally distributed through the thallus *) the green or bluish-

* This regular distribution making our type one of the *Homoiomerous* lichens.

green cells ("gonidia") of the *algal* or *schizophyte* constituent,* the whole being embedded in a homogeneous jelly. The two plant elements are said to live in *reciprocal* parasitism,† but it would be nearer the truth, perhaps, simply to say that the *fungus* is parasitic on the alga, giving it in return for organic food merely some degree of protection, which may not be urgently needed, and humidity. The algal and fungal constituents *can* vegetate independently of each other.

Reproduction.—1. Asexual. Single gonidia or groups of gonidia become closely invested in hyphal tissue, and by rapid isolated combined growth exercise sufficient pressure on the outer part of the thallus to rupture it. These *soredia*, as they are called, when set free are able to grow at once into a new Lichen-thallus. 2. Sexual. Spores are formed in fructifications (*sporocarps* or discocarps), which are the results of separate sexual acts.

In its earliest stage the sporocarp answers to the procarp of Polysiphonia, and is at first a stout lateral branch on a hypha of the thallus. The lower part (*archecarp*), which is sunk in the thallus, is twisted like a screw, and the upper part lying above it is a multicellular filament (*trichogyne*), which always appears on that side of the thallus exposed to the light. The *spermatia* (see page 118) are produced in special receptacles or *spermogonia*, which are cavities in the thallus lined or filled with *sterigmata* (see page 126), from which the spermatia are derived in large numbers by abscission, and escape through a narrow aperture in the spermogonium in the time of wet weather, spreading out over the surface of the thallus, and so coming in contact with the sticky surface of the trichogyne of the female. Conjugation occurs between them and the trichogyne, and the result or effect is transmitted to the archecarp, which afterwards increases in size, multiplies its cells by intercalary growth, and becomes invested with a coil of the surrounding hyphæ. Lateral branches now grow out from the archecarp and become *asci*, while the rest of the parts which go to constitute the sporocarp are produced by a process of growth

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* Belonging to the Cyanophyceæ (see page 102).

† This living together in union, the one individual receiving so much from the labour or protection, &c., of the other is known as *symbiosis*.

in the hyphæ adjacent to the archecarp. For the parts of the sporocarp see the Figure below.

FIG. 98.—*Anaptychia ciliaris*, a small portion of the apothecium (sporocarp) in vertical section; *m*, medullary layer of the thallus, *y*, the sub-hymenial layer, *p*, paraphyses of the hymenium; between them are the asci in different stages of development; in 1 the young spores are not yet septate, in 2-4 the spores are more advanced; the protoplasm in which they are embedded is contracted by the drying up of the Lichen before the preparation was made (× 350). (After Goebel.)

The thallus forms a rim or *excipulum* (the sub-hymenial layer in the figure) round the ripe sporocarp. The ripe spores

are set at liberty when water finds its way to hymenium. The ascospore germinates in moisture by the production from the endosporium of a hyphal filament, which branches and spreads over its substratum, and when it becomes confluent with the proper algal cells a thallus is built up.

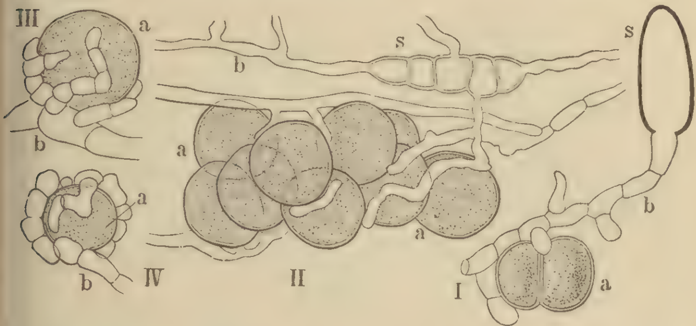

FIG. 99.—Represents some examples of the symbiosis of hyphæ and gonidia, such as have actually been seen to occur in experimental culture. In I. we have a germinating spore of a Lichen, *Physcia parietina* (*s*). From it has issued the filament (*b*) which is just about to attach itself to an Alga (*a*, *Protococcus viridis*). II. represents a spore (*s*) of *Biatora muscorum*, the hyphæ (*b*) of which are intertwined with the *Protococcus* colony (*a*). In III. and IV. single gonidia (*Protococcus* cells) from the thallus of *Cladonia furcata* are shown, so as to illustrate their connection with the hyphæ. (After Behrens.)

Life History.—1. Collema; 2. Soredium; or Ascospore from sporocarp, the result of sexual act. 1. Collema.

Puccinia graminis.

This is a *parasite* which completes its life cyle on *two different hosts* (*metoxeny*), on one of the Gramineæ (wheat or secale usually) and on the Barberry. In the wheat leaf and stem it forms a vegetative intercellular mycelium, from which short bud-stalks (*gonidiophores*), each bearing a terminal-warted yellow or orange unicellular bud (*gonidium*), are protruded to the surface through the epidermis ruptured by the growth of the fungus (see Fig. 100, *III*, *ur*). This is the *Uredo* or Rust of wheat stage. These uredo-buds become detached, and are ready to germinate on any suit-

able neighbouring wheat (or other grass) leaf or stem, where they again develop mycelia and uredospores. Later on in the season short bud-stalks, each with a terminal thick-walled bicellular brown bud (*teleutogonidium*), are produced, and the life of the uredo ends with the production of this—the *Puccinia* or Brand of wheat stage (Fig. 100, *II*, *t*).

The teleuto-buds remain in a resting state on the grass shoots till the following spring, when they send out short septate germ-tubes (*promycelia*), the terminal cells of which give rise at once to *gonidia* (unicellular) on slender branch-processes. These promycelial gonidia can only develop a new mycelium when they germinate on a leaf of the Barberry. When they get transferred to this new host they develop a tube which pierces the epidermis and passes through it into the interior, where it gives rise to a mycelium (the active growth and fructification of which cause a great swelling in the leaf).

On the upper surface the mycelium produces *spermogonia*, each of which is an urn-shaped receptacle in an enveloping layer of hyphæ (Fig. 100, *I*, *sp*). The cavity of the spermogonium is lined with hair-like filaments that project through the epidermis beyond the aperture of the spermogonium like a camel-hair brush. The bottom of the spermogonium is covered with short slender hyphæ that give off *spermatia* by abscission. The part played afterwards by the spermatia is unknown.

Later, on the under side of the leaf, *æcidia* or globular bodies composed of parenchyma, each surrounded by a layer of hexagonal cells, and enclosed in an envelope of delicate hyphæ, make their appearance. The æcidium or *sporocarp** forms first within the epidermis, but when it reaches maturity it bursts this tissue, also rupturing its own apical bounding layer (*periderm*), and appears as an open cup full of cells, which are continually and basipetally developed by abjunction from the hyphæ of the hymenium (see page 121) at the bottom of the cup. These free cells or *æcidiospores* scatter and germinate so as to develop a mycelium only when they get on to the surface of the leaf or stem of one of the Gramineæ (grasses). Then the germ-tubes produced work

* As far as yet known this arises *apogamously* (see page 98).

their way *through the stomata* into the parenchyma, and there give rise to a mycelium from which uredospores are again developed.

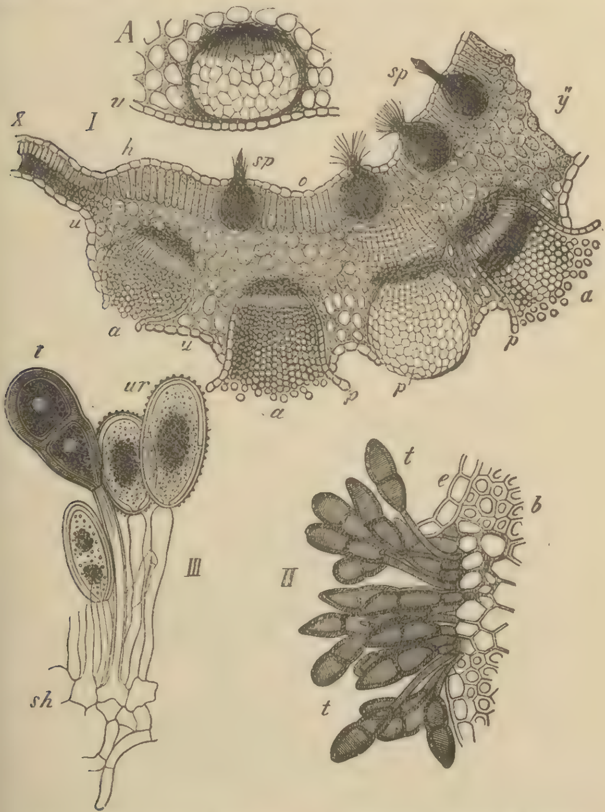

FIG. 100.—*Puccinia graminis.* I. Transverse section of a leaf of Berberis, with Æcidia (*a*); *p*, the wall of the Æcidia; *u*, lower, *o*, upper surface of the leaf, which has become thickened at *u*, *y*, in consequence of the presence of the parasite; on the upper surface are Spermogonia (*sp*). *A*, a young Æcidium which has not yet burst. II. Layer of Teleutogonidia (*t*) on the leaf of *Triticum repens*; *e*, its epidermis. III. Part of a layer of Uredogonidia on the same plant; *ur*, the Uredogonidia; *t*, a Teleutogonidium. (After Sachs.)

Life History.—1. Puccinia; 2. Uredogonidium, or Teleutogonidium, giving rise to mycelium with Æcidiospores *apogamously?* developed. 1. Puccinia.

Agaricus campestris (Common Mushroom).

A *saprophyte* living on humus, in which its widely-ramifying *anastomosing mycelium* spreads. From the latter fructifications (*sporocarps*) arise. These are at first pear-shaped solid bodies composed of uniform hyphæ, which tissue however soon gives way in such a manner as to form an *annular* air-space beneath the summit of the stalk or *stipe*. As growth proceeds this cavity enlarges with the whole body, its upper wall forming the under side of the *pileus* or cap (see figure below), from which the familiar radially-disposed *hymenial lamellæ* grow in a downward direction, and eventually quite fill up the air-space. At this stage the margin of the pileus is still directly connected with the stalk by hyphæ, which run from it down to the base of the stipe.

By continued growth the central portion of the stipe becomes elongated, and the distance between it and the margin of the pileus increased, so that the connecting

FIG. 101.—*Agaricus campestris* (Mushroom). I. Young fructification, with mycelium (*m*). II. Fructification almost mature; *c*, Stipe; *r*, Remnant of ruptured *velum partiale*; *h*, Pileus; *b*, Lamellæ; nat. size. (After Behrens.)

hyphæ referred to become stretched and separate outwards from the stipe from below upwards, forming a membranous *veil* running from the stipe to the edge of the pileus. By and by the growth of the pileus makes it spread

out more horizontally, and the membrane (or *velum partiale*) is torn from its margin and hangs down like a frill on the stipe.

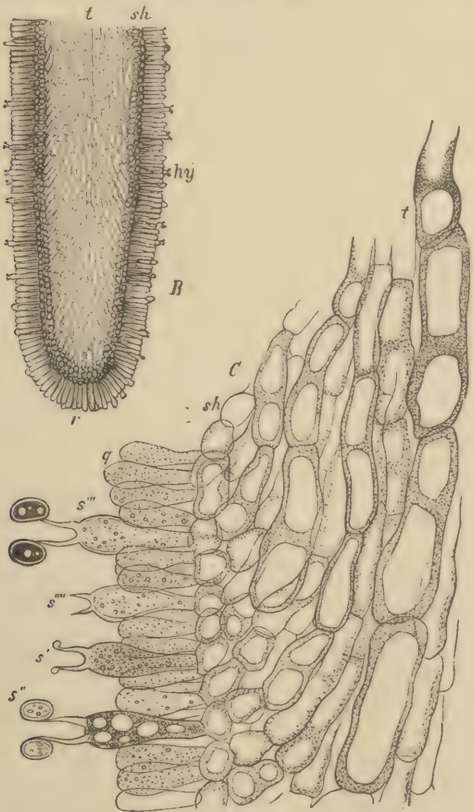

FIG. 102.—*B*, a tangential section of a lamella, highly magnified; *hy*, the hymenium; *t*, the central tissue called the Trama. *C*, a portion of the same section more highly magnified (× 550); *q* and *s*, hymenium of basidia *s'''* (with intermixed paraphyses,* *q*); the former with basidiospores (*s''*) and sterigmata, in different stages; at *s'* the spores have fallen off; *sh*, sub-hymenial layer; *t*, portion of the Trama. (After Prantl.)

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* Sterile cells.

The figure gives a better idea of the structure of one of the lamellæ projecting on the under side of the pileus than could be obtained by any amount of printed description.

The basidiospores, after detachment by abscission, germinate on the surrounding or distant soil, and produce a new mycelium from which the life-cycle again starts.

Life History.—1. Agaricus (Mushroom); 2. Basidiospore, from *apogamously* developed Sporocarp. 1. Agaricus.

Class VI.—Hepaticæ.

The division Muscineæ, of which this is the lowest Class, exhibits a sharply-defined alternation of generations—a sexual (*oophyte*) generation which produces sexual organs, alternating with an asexual (*sporophyte*) generation that gives rise only to spores. The *sexual* generation is by far the more prominent of the two, and is *rich in chlorophyll* and *self-supporting*. It does not spring, however, directly from the germinating spore, but from a simpler multicellular filamentous or plate-like structure (*protonema*) to which that body gives rise. From the protonema (which is usually small and unimportant in the Hepaticæ) the sexual generation arises as a lateral or terminal shoot. Fertilisation in the female (archegonium) produces the asexual generation in a structure quite different from that of the sexual. It is not organically connected with the body of the latter, but derives its subsistence from it, and in outward appearance is simply its "fruit." A sporophyte of this nature is a *sporocarp*, as already explained, but is usually called a *sporogonium*.

Hepaticæ.—The *sexual generation* in the Hepaticæ is either a flat dichotomously-branched thallus, with or without leaves, or a filiform stem with two or three rows of leaves. There is always, with two exceptions (Riella and Haplomitrium), a decided dorsi-ventral growth (upper and under surface formation); the free side, which is turned to the light, having a different organisation from that of the under-shaded side, which very commonly clings to the substratum. The sporogonium or *sporophyte* remains enclosed till the spores are ripe, and *never opens by the separation of a special*

operculum as in mosses, but in a valved or irregular fashion, or rarely not at all. The leaves are composed of a single layer of cells, and the rhizoids are unicellular.

Hepaticæ may be divided into two Sub-Classes:—

1. Marchantiaceæ.—With thallus or thalloid stem. The capsule of the sporocarp opens regularly, or irregularly, or not at all.

   Types.—Riccia, Marchantia.

2. Jungermannieæ.—With slender filiform stem or thalloid body. The capsule splits from above downwards into four valves or two.

   Types.—Jungermannia, Radula.

Marchantia polymorpha (Liverwort).

The *vegetative* body is a *dorsi-ventral dichotomously-branched thallus*, which spreads out on the ground, and is fixed to the substratum by *rhizoids*. The thallus has a mid-rib portion, and is several layers of cells in thickness. The under side has two rows of scales and *two kinds of rhizoids*—(1) simple tubular elements, and (2) tubes with peculiar thickenings which project into their cavity. The upper side has *stomata of remarkable structure* in the epidermal layer. The stomatic

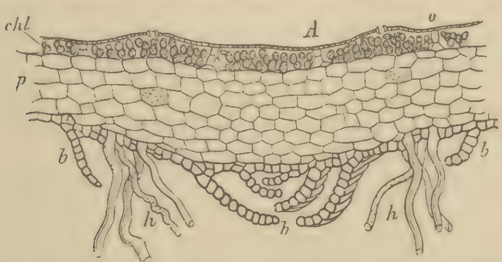

FIG 103.—Transverse section through the thallus of *Marchantia polymorpha*. *A*, middle portion with scales (*b*) and rhizoids (*h*) on the under side (× 30). (After Goebel.)

aperture is a circular canal, and is *formed by several tiers of cells*. These lead into a wide air-chamber, over which the *epidermis is supported like a roof* by occasional cell-pillars springing from the ventral white tissue of the thallus (Fig. 103).

Into those air-cavities distinct conferva-like chlorophyll bearing cells grow up from the bottom cells, budding or sprouting somewhat like yeast as they proceed (*chl*, Fig. 103).

Reproduction.—1. Asexual. By bilaterally symmetrical brood-buds or *gemmæ* (see page 71), produced in broad cup-like receptacles on the dorsal or upper surface of the thallus. They arise as cellular papillæ on the bottom of these cups, and their terminal cell develops into the flattish body of some size which constitutes the gemma; between them are club-shaped hairs, the walls of which become disorganised or changed into mucilage, and the gradual swelling of this material forces the gemmæ out of their receptacles. On the margins of the mature gemmæ there are indentations right and left, from which the first flat shoots or thalli appear after the former have fallen out of their cups and become exposed on damp ground to the action of daylight.

2. Sexual. Monœcious or diœcious.

The *antheridia* (males) and *archegonia* (females) are borne on separate special upright branches (*antheridiophore* and *archegoniophore*) on the upper side of the thallus. The summit of the antheridiophore is an expanded disc with notched margins. The *upper* surface of this disc is studded with minute openings, leading into little cavities, springing from the base of each of which is an oval ascending antheridium. The antheridia, however, really originate on the surface of the thallus, but *get grown over* by temporary energetic local growths of the latter around the male organs. The antheridium consists of a short-stalked oval body with an outer wall formed of a single layer of cells, the interior being filled with innumerable very small *spermatocytes*, or mother-cells of the *spermatozoids*. The stalked disc of the archegoniophore is divided into a number of radiating lobes, and on the *under* surface of each of these, or from the disc portion between them, a number of archegonia are placed in rows. the margins of the lobes growing down and forming a sort of investment (*perichætium*) to them, like a curtain on each side. The figures below (104, 105) make the appearance and structure of the antheridia and archegonia plain.

Development of the Sexual Organs.—The antheridium begins as a papillose protuberance on a cell which is soon

cut off by a cross wall. This papilla cell next divides into *two* cells—a *lower*, which produces the stalk, and an *upper*, from which the body of the organ (wall layer and spermatocytes) is developed. The archegonium likewise begins as a papilla cell, which divides into an upper and a lower, the latter becoming the stalk, and the former the archegonium body, the mother-cell of which divides by three longitudinal walls forming three outer cells, with a central cell overtopping these. The outer three next form five or six envelope cells by *radial* longitudinal septa, while the central

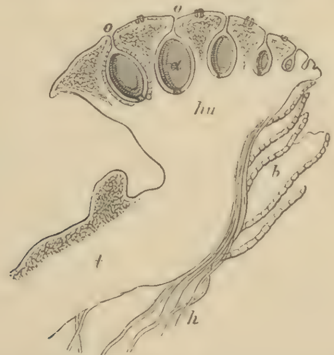

FIG. 104.—Vertical longitudinal section through a male receptacle, *hu*, which is still developing, and the part of the flat shoot from which it springs; *bb*, scales; *h*, rhizoids in a ventral channel of the receptacle; *oo*, the openings of the cavities in which the antheridia, *a*, are placed. (After Goebel.)

cell divides by a cross wall into an upper or lid cell and an inner or lower cell. The structure continues to grow, and we now have the six envelope cells dividing transversely, and the *innermost* cell also dividing transversely, making two storeys, the lower becoming the *venter*, or, afterwards, swollen basal part of the archegonium, and the upper the *neck*. The inner cell of the newly formed venter, called the *central cell*, now increases in size, and divides transversely so as to make a larger lower cell (the *ovum* *) and an upper smaller cell (the *ventral canal cell*). The neck of the

* Which rounds off and becomes rejuvenated in its central cell.

archegonium, meanwhile, goes on elongating, and the last-named cell divides into four, eight, or sixteen, long narrow cells, the *neck canal cells.* The *mature* wall of the venter, which is composed of one or two cell layers, and the wall of the neck of five to six longitudinal rows of one layer, are completely fashioned, in the former instance, by further longitudinal and cross divisions in its outer cells, and in the latter (giving it increased length) by transverse divisions in the wall cells, and the lid or cap cell divides into five or six cells, forming the lid of the neck.

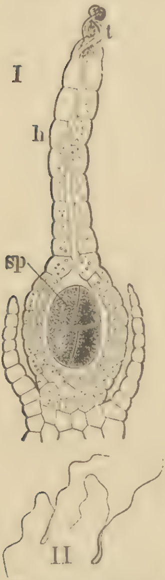

FIG. 105.—I. Archegonium of *Marchantia Polymorpha* (× 300). II. Spermatozoids of do. (× 800). *sp*, divided ovum after fertilisation; *h*, neck of archegonium; *t*, dried apex of do. (After Behrens.)

During the rounding off of the ovum, preparatory to fertilisation, the longitudinal walls of the neck, canal cells, and the cross wall beneath the ventral canal cell, swell up into mucilage, which forces out the protoplasm of all the canal cells through the opened lid at the apex.

The mature antheridium, when bedewed with moisture, bursts its wall at the top, the contents are gradually poured out into the water, and the spermatocytes become isolated and eventually rupture, the spermatozoids issuing from them as slender spirally twisted threads, with two long and very delicate cilia at the ends.* In wet weather the spermatozoids find their way to the archegonia, but *how* is not exactly known; possibly as they occur often on sloping and perpendicular surfaces, the rain just washes the male elements to the near vicinity of the females, there to pass along the perichætium and into the slimy canal of archegonium neck.

* The spermatozoid, which usually carries a small and delicate vesicle attached to its hinder end, is formed chiefly from the nucleus of the mother cell, which grows more dense towards the circumference, and this separates forward into the screw thread of the body, while the central looser part forms the vesicle behind.

As the result of fertilisation, the ovum segments holoblastically, and the first wall formed is at right angles to the lower axis of the archegonium (*1*, *1*, Fig. 106). Both the upper and lower cells of this then go on dividing (and growing) till each gives rise to four, the upper set of which originates the young *capsule*, consisting of a layer of cells forming the wall and inner cells (*archesporium*), from which the spores and elaters (see below) proceed, and the lower the *stalk* of the sporogonium or sporophyte (Fig. 106). The basal portion of the lower tier of cells below the very short stalk develops a thickened foot, the function of which is that of an absorber of nutriment from the mature plant body through the archegoniophore, which it penetrates for some little distance. The capsule continues to develop and grow, and eventually ruptures the venter of the archegonium at the upper part, and afterwards its own apex, allowing the ripe spores to escape, the exit of which is hastened by the action of the *elaters*, or sterile spindle-shaped cells with spiral thickening, which line the inner wall. These elaters are very susceptible to the state of the atmosphere, and readily jerk out the spores, when they suddenly contract.

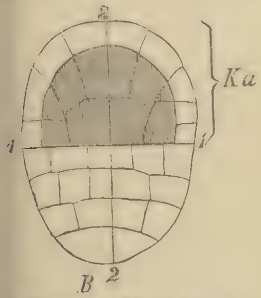

FIG. 106.—*Marchantia*; the Oosphere is divided by the first wall, formed in it after fertilisation, into a lower portion which becomes the stalk, and an upper which forms the capsule *Ka*. The shaded portion is the archesporium. (After Goebel.)

The spore in germinating sends out a germ-tube, which grows towards the light, swells at its apex and forms a disc (*protonema*), from the marginal cells of which the young plant develops into the thalloid form of the sexual adult.

Life History.—1. Marchantia with sexual organs (oophyte); 2. Gemma; or Spore in Sporocarp (sporophyte). 1. Marchantia (oophyte).

CLASS VII.—MUSCI.

The protonema is a filamentous structure, or, more rarely, a flat expansion, on which the moss plant proper arises as a

monopodially branched lateral *stem and leaf shoot.* On the apical portion of this plant the sexual organs are formed, and the sporogonium (sporophyte) is produced from the ovum in the archegonium. The latter body grows vigorously as the sporogonium develops, and is converted into the *calyptra*, which is usually afterwards ruptured at the base and carried up by the elongating structure as a cap on the sporogonium. The capsule which forms at the upper part of the sporogonium has its wall composed of several layers of cells, and the *whole inner tissue is never employed in* the production of spores, the great part of the central tissue constituting the so-called *columella.* The capsule usually opens by the removal of a distinct operculum. Elaters are never present.

There are four groups of Musci :—

1. Sphagnaceæ.—Calyptra remains attached to the base. *Type.*—Sphagnum.

2. Phascaceæ.—Capsule does not open at all. *Types.* Phascum, Archidium.

3. Andreæaceæ.—Capsule splits into four valves. *Type.* —Andreæa.

4. Bryineæ.—Capsule opens by throwing off an operculum, which is from the first differently constructed to the rest of the capsule. *Types.* — Funaria, Polytrichum, Tetraphis, Hypnum, Fontinalis.

Funaria hygrometrica (Cord Moss).

The oophyte generation is the moss-plant proper, consisting of a stem with leaves and rhizoids. A frequent form of shoot is the stolon, which eventually rises and produces erect shoots. The structure of the stem can be made out from Fig. 107.

The growing point of the stem is a three-sided pyramidal *apical cell*, with the broad convex base uppermost at the apex of the stem. From this three rows of *segment cells* are produced, each of which at the beginning divides by a longitudinal wall (leaf-wall) into an inner and an outer cell ; the latter goes on to form, by further divisions and growth,

the cortex of the stem and a leaf, and the former produces the central tissue of the stem.

The rhizoids appear in great numbers from the base of the stem (Fig. 107), where they originate as tubular outgrowths of the epidermal cells, and elongate by apical growth, becoming septate as they advance by the formation of oblique transverse walls. The growing end of the rhizoid is white or hyaline, and its walls are thin, while the older parts have a thicker brown wall. It generally branches below the soil.

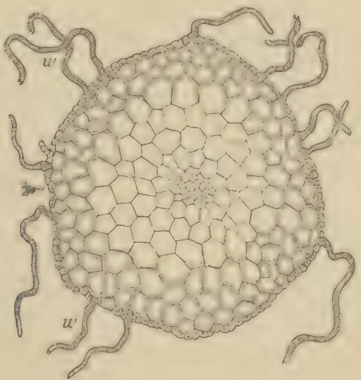

FIG. 107.—Transverse section of the base of the stem of *Bryum roseum*, with epidermis bearing rhizoids (*w*); thick-walled cortical part; clear thin-walled fundamental tissue; and in the very centre a rudimentary vascular bundle; × 90. (After Goebel).

Morphologically, there is no sharply-defined line between the rhizoid and the protonema; the latter develops some of its branches as rhizoids, and the rhizoids are capable of developing single upward-growing branches as protonema.

The leaf originates as a papillose protuberance of a segment cell (see above), which gets cut off by a wall. The basal portion of this cell goes to form the outer tissues of the stem; the upper becomes the apical initial cell of the leaf, and gives rise to two rows of segment cells, inclining right and left. The apical growth of the leaf, however, is limited, and when it ceases the further development proceeds

basipetally, by the formation of new members from those segment cells.

The foliage leaf is traversed by a mid-rib of narrow

FIG. 108.—Longitudinal section of the summit of a very small male plant of *Funaria hygrometrica*; *a*, a young, *b*, an almost mature antheridium in longitudinal section, showing wall of one layer of cells and spermatocytes within; *c*, paraphyses; *d*, leaves divided through the mid-rib; *e*, through the lamina (× 300). (After Goebel.)

elongated cells (rudimentary vascular bundle), many of which resemble those of the central bundle of the stem

(see Fig. 107), and these sometimes pass on to the latter as leaf-trace bundles. In the vicinity of the mid-rib the leaf is two or three cells thick, but at the marginal parts it is only one cell thick.

Functions.—As the leaves are green, the functions of stem, leaf, and root (rhizoids) will be those of the typical kinds, and need not be described here (see pages 55, 58, 61).

Reproduction. — 1. Asexual. Common, by the production of buds and secondary protonemæ, both of which the moss-plant is capable of producing from any part above or under ground. The formation of a new plant-shoot is, however, always preceded by the production of a protonema, even when it proceeds from gemmæ. A vigorous leaf, when detached, may also propagate the race by sending out protonemæ, from which leafy shoots arise. 2. Sexual. These organs in this type are found on the extremity of a primary leafy axis, enclosed in an envelope of leaves (the *perichætium*), and mixed with paraphyses or sterile cells (Fig. 108, *c*). The species under consideration is *diœcious*. The male plants are frequently smaller and of shorter duration than the female. The general appearance and parts of the male and female "flowers" can be made out from Figs. 108, 109.

FIG 109.—*Funaria hygrometrica.* *A*, longitudinal section of the summit of a weak female plant (× 100); *a*, archegonia; *b*, perichætium. *B*, an archegonium (× 550); *b*, venter with the ovum and ventral canal cell above; *h*, neck with neck canal cells beginning to be converted into mucilage, which will force asunder the four-lid cells, *m*; *s*, stalk (below venter). (After Prantl.)

The first formed antheridium, and archegonium, arise from the

apical cells of the male and female shoots respectively, those that follow are developed from the youngest normal segment cells.

The *antheridium mother cell* gets cut off from the stem-cell, and divides transversely into a lower cell from which the stalk arises, and an upper which develops further into the body of the antheridium, as shown in Figs. 110, 111.

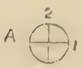

FIG. 110.

FIG. 111.

In *B* the central cell mass or *archesporium* (*c*) divides greatly, forming the mother-cells (spermatocytes) of the spermatozoids, and the outer ring, by further divisions, gives rise to the one-layered wall. (The inner tissue produced from this, however, immediately outside the archesporium, becomes the *tapetum* or temporary food-layer for the maturing spermocytes.)

The *archegonium mother-cell* divides also at the start transversely, the lower cell going to make the stalk and the upper the body of the organ. In the upper cell two oblique longitudinal walls are then formed; the oblique cells thus produced incline in opposite directions, and give rise to the tissue of the venter and of the upper part of the stalk. The

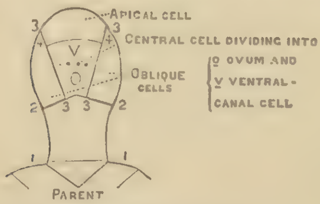

FIG. 112.—Longitudinal section of developing Archegonium.

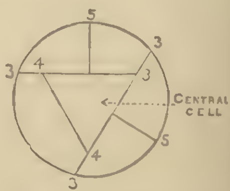

FIG. 113.—Transverse section of Venter of developing Archegonium.

uppermost cell of all now left, after cutting off the central cell by a cross wall, develops as an apical cell, and by successive longitudinal divisions produces tiers of cells which give rise to the long neck, consisting externally of six exterior rows, and internally of the canal cells. The central cell divides by a transverse wall into a smaller upper

cell (*ventral canal cell*) and a larger lower cell, the protoplasm of which contracts and forms the *ovum*. See Figs. 112, 113, above, showing the development of the archegonium, and Fig. 109, *B*, for a mature archegonium.

When ripe, the wall of the antheridium in moisture bursts at the top, and the spermatocytes come out, the walls of which have previously undergone a mucilaginous change. The mucilage dissolves in the water, and the spermatozoids are set free and find their way to the ripe archegonia of a neighbouring plant.

FIG. 114.—*Funaria hygrometrica*. *A*, an antheridium bursting; *a*, the spermatozoids in their mucilaginous cysts (spermatocytes), one of which in *b* is more highly magnified; *c*, a free spermatozoid (× 800). See also Fig. 108. (After Prantl.)

After fertilisation the ovum holoblastically segments; and as the oospore develops the sporogonium (sporophyte), the venter of the archegonium grows vigorously, and is transformed into the temporary projecting layer known as the *calyptra*, which is eventually ruptured at its base by the elongating and still rodlike sporogonium, and carried up as a cap before the development of the capsule in the upper part of the latter.

In giving rise to the sporophyte embryo, the ovum divides into a *hypobasal* and an *epibasal* cell. The former goes to make the foot of the embryo that grows down a little way into the oophyte (moss plant) and acts as a "nurse" or agent, which takes in nourishment from the oophyte and transmits it to the growing parts above. The epibasal cell divides by usually two transverse walls, and then, as growth proceeds, two oblique walls going in opposite directions form in the uppermost cell, and in this way a two-sided apical cell is ultimately produced, which cuts off a number of segments

that become disposed as transverse discs. Fig. 115 is a diagrammatic section of a very young developing embryo.

The *capsule*, which develops later from the upper portion of the elongated sporogonium, is at first a solid mass of homogeneous tissue, the differentiation of its interior beginning with the formation of an annular intercellular space, which, developing greatly, separates practically, *except at top and bottom*, the wall, composed of several layers, from the central tissue. The two, however, are connected in some sense across the intervening space by green protonema-like cell filaments. The third or fourth layer of the central tissue, counting from the annular air cavity, is the *archesporium* (see page 79), which by division produces the spore mother cells, that become separate from one another by the deliquescence of their walls. These, by endogenous divisions, give rise to the free spores. The cell layers which partition the great air space from the spores is known as the *outer spore-sac wall*,* while the layers which bound them within is the *inner spore-sac wall*.* The inner large celled axial tissue without chlorophyll is the *columella* (Fig 116). The spore-sac is ruptured by the removal of the *operculum* (lid of capsule) † and the spores set free. The margin of the capsule, after the removal of the operculum, is seen to be occupied by a series of very regular and delicate teeth, which together constitute the *peristome*.

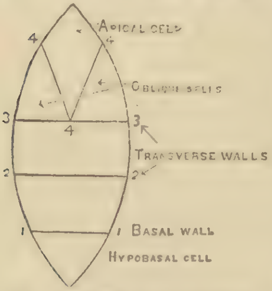

Fig. 115.—Diagrammatic longitudinal section of developing Embryo of Funaria.

When the spore *germinates* it does so in the customary way, by protrusion of the endosporium after rupture of the exosporium, producing a tubular septate branching outgrowth, which has unlimited power of elongation by apical

* The two walls, together with their spore contents, constituting the *sporangium*.

† The removal is effected, usually, by an annular layer of epidermal cells *annulus*) below it, being thrown off by the swelling of its inner walls.

growth. This is the protonema from which the proper moss plant, or oophyte, is again developed by budding.

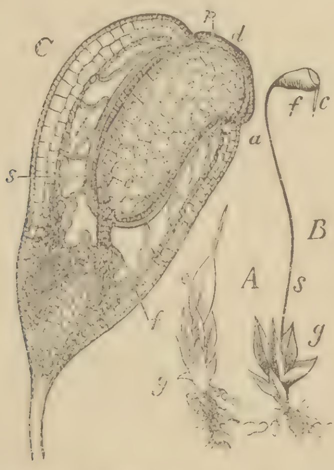

FIG. 116.—*Funaria hygrometrica.* *A*, a young leafy plant (*g*) with the calyptra (*c*). *B*, a plant (*g*) with the nearly ripe sporogonium; *s*, its seta; *f*, the capsule; *c*, the calyptra. *C*, Longitudinal section of the immature capsule bisecting it symmetrically; *d*, operculum; *a*, annulus; *p*, peristome; *c*, *c'*, columella; *h*, air-cavity; *s*, archesporium. (After Sachs.)

Life History.—1. Moss plant (oophyte); 2. Bud or Secondary Protonema; or Spore (sexually developed) producing Primary Protonema, from the budding of which we again get—1. Moss plant.

CLASS VIII.—FILICINEÆ.

The *oophyte* * is never anything but a small and delicate thallus (*prothallium*), which almost invariably dies directly the development of the sporophyte has begun and advanced to the *first* stage. This prothallus is usually green † and monœcious, but is diœcious when two kinds of spores are

* Compare with Musci.
† And having rhizoids as well as chloroplasts is capable of independent life (see Fig. 123).

produced (Heterosporous Ferns). The *sporophyte* is an unbranched or sparingly branched stem with large and usually branched leaves, and generally numerous roots of typical structure. The *sporangia*, which are modified trichomes or hairs (see page 44), are numerously formed on ordinary or metamorphosed leaves, and usually collected in small groups (*sori*). The *archesporium* is a single cell.* Stem and root have an apical cell, and in each (as in a lesser degree in leaves) *vascular bundles* are strongly and *concentrically* developed, the central *xylem* consisting chiefly of tracheids (see page 38) with scalariform thickenings (see page 24), and being surrounded by soft *phloem* elements.

There are two sub-classes, A and B :—

A. Leptosporangiate Filicineæ.—Sporangia formed from a *single* epidermal cell.

There are two groups in this sub-class, 1 and 2 :—

1. Homosporous group.†—Spores of one kind only. Prothallus green, independent, monœcious. This group contains six Orders :—*a*, Hymenophyllaceæ ; *b*, Cyatheaceæ ; *c*, Polypodiaceæ ; *d*, Gleicheniaceæ ; *e*, Schizæaceæ ; *f*, Osmundaceæ.

2. Heterosporous group.—Spores of two kinds always produced—*Macrospores*, producing *female* prothalli, and *Microspores*, producing *male* prothalli. The prothalli produced by the former do not separate from the spores, and those produced by the latter are very rudimentary. There are two Orders :—*a*, Salviniaceæ ; *b*, Marsiliaceæ.

B. Eusporangiate Filicineæ.—The sporangia spring from a *group* of epidermal cells. The species are all *homosporous*. There are two orders :—*a*, Ophioglosseæ ; *b*, Marattiaceæ.

Type of Homosporous Leptosporangiate Fern.

Aspidium Filix Mas (Male Shield Fern).

The Fern-plant is the *sporophyte* (compare with Musci). It is perennial, and consists of an obliquely-ascending

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* Compare with Musci. † Common Ferns.

rhizome stem which bears *leaves* that form the most conspicuous portion of the whole plant, and secondary lateral (adventitious) *roots*. From superficial parts on those members typical and variously modified hairs arise. The leaves and roots develop acropetally, and the branching of the latter and of the stem is monopodial.*

The *Stem*.—Is nearly of equal thickness throughout its length, and is roughly cylindrical. Its surface is covered by the persistent bases of the leaves, and the basal portions of those members are densely invested with numerous peculiar brown leaf-like scaly *hairs*, known as *chaff scales* or *ramenta*; the latter also entirely cover over and conceal the young *circinate* (see page 74, and Figs. 57 and 118) leaves at the

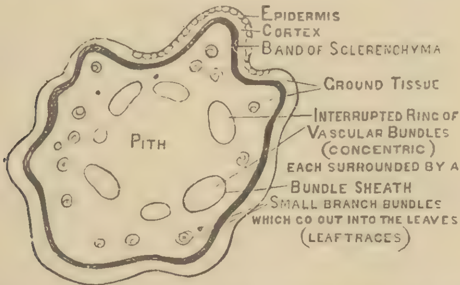

FIG. 117.—Diagrammatic Cross Section of Stem of Aspidium. Note the very irregular outline.

growing apex. The general anatomy of the stem can be readily learned from Fig. 117.

The central system of larger bundles shown in Fig. 117 are observed to form, as they run up and down through the stem, a continuous *network* with large meshes (see Fig. 118, *F*); each mesh being opposite the point of insertion of one of the leaves, and therefore known as a *foliar-gap*. The vascular bundles that pass out into any leaf are given off from the margin of its own mesh (Fig. 118, *F*).

The growing apex of the stem is broad, and is covered

* But not axillary as in Phanerogam stem branching.

over by young leaves with circinate ptyxis, and with large quantities of ramenta (Fig. 118, *D*). The apical cell is a three-sided pyramid in this type, the cells surrounding it, and which have been cut off from it, are the segment cells. The diagram below can make all this clearer than words (Fig. 119).

The stem dies off at its base (hinder end) as it advances in front. The lateral buds are not axillary, but are produced

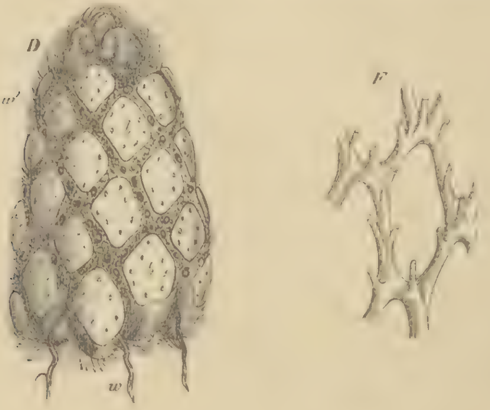

FIG. 118.—*D*, extremity of the stem of Aspidium from which the leaves have been cut off at the base of the stalks, the youngest leaves only of the terminal bud being retained in order to show the arrangement and ptyxis of the leaves; the spaces between the leaf-stalks are filled with numerous roots (*w*, *w'*), all of which have sprung from the stalks. *F*, a mesh of the net-work slightly magnified, showing the basal portions of the bundles which pass out into the leaves. (After Goebel.)

on the posterior side of the bases of the leaves, or on one of the lateral edges of the leaf-stalk when adventitious.

The Foliage Leaf.—Parts: *Petiole*, traversed by two lateral longitudinal ridges, and the pinnately-branched compound *Lamina* or blade. The branching of the lamina is repeated. The leaf-stalk supports numerous *pinnæ*, or first and chief blade pieces, arranged in two lateral rows corresponding to the ridges on the stalk. The segments or

branches of the pinnæ are *pinnules*. The venation of the pinnæ is pinnate and *bifurcate* at the extremities of the veins. On the under side of many of the pinnæ *sori* or groups of small *stalked sporangia*, covered by an indusium, can be observed. The *development* or growth of the leaf is *apical and basifugal*. The petiole is first made, and then the blade begins to form at its apex, the lowest parts being developed first, and then the parts above, in strict basifugal succession. The growth is extremely slow; the whole of a rosette of leaves of this type taking two years to form. The

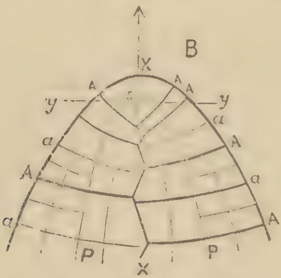

FIG. 119.—Diagram showing the arrangement of cell-walls, as seen in a medium longitudinal section through an apical cone, with a pyramidal apical cell. *A*, *A*, are the segmental walls, which form part of the system of anticlinals; *a*, *a*, walls by which each segment is cut into two equal halves, these complete the anticlinal curves; *P*, *P*, periclinals, which are not completed up to the apex. (After Sachs.)

rudiment of the leaf is formed by the arching out of a single cell at the growing point of the stem. The growing point of the young leaf is either from the first a group of marginal initial cells, or a two-sided wedge-shaped apical cell. The branches of the blade arise from a group of initials formed below the principal growing apex.

Anatomy of the Blade.—On the outside we have a regular *epidermis*, with a thin cuticle,* forming the exterior layer of the upper and under surface. *Stomata* are *only* found on the under surface; each has *two guard cells*, as is usual in

* The epidermal cells of Fern leaves contain chloroplasts, but those bodies are as a rule absent in the epidermal cells of Phanerogams.

the higher plants (see page 42 and Fig. 35). Within the epidermis is the *mesophyll*, consisting of thin-walled parenchyma, the cells of which towards the under surface are less regular in outline, and enclose larger intercellular spaces than those near the upper surface. Here and there embedded in the mesophyll are cylindrical *vascular bundles** (veins), each of which are enclosed in a bundle sheath (Fig. 120). A transverse section of the petiole shows proceeding from the outside:—epidermis, cortex, crescent-like arrangement of vascular bundles, sclerenchyma sheath, and ground tissue.

FIG. 120.—*Aspidium Filix Mas.* *A*, transverse section of a leaf with a sorus, consisting of the sporangia (*s*), and the indusium, (*i*, *i*); a small vascular bundle is seen on each side in the mesophyll of the leaf, the cells of the sheaths showing the dark brown thickenings on the inner walls. (After Goebel.)

The Root.—Small simple organ; form, cylindrical; brown or black in colour; covered in the younger parts with a felt of numerous hairs; branching, *endogenously* and monopodially. The apical region is depicted anatomically in Fig. 121, and the structure of the older parts is seen in Fig. 122.

Lateral roots arise from the *endodermis* (bundle sheath), which here performs the same functions as the pericambium in higher plants. The mother-cell of a lateral root forms first a three-sided apical cell, and from this the first segment of the root cap proceeds (see Fig. 121). In its subsequent growth the cortex is simply broken through.

* The vascular bundles in the leaf show a tendency to a collateral arrangement, the xylem being nearest to the upper surface. Compare with stem.

The *Functions* of the roots and shoot of ferns are typical,

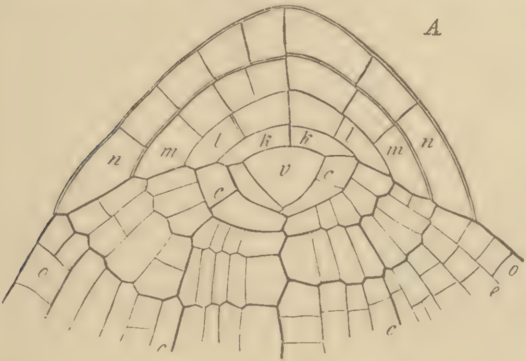

FIG. 121.—Apical region of fern-root. Longitudinal section through the extremity of a root of *Pteris hastata* ; *v*, apical cell ; *k*, segment of the same reaching to the root-cap ; *k*, *l*, *m*, *n*, layers of the root-cap ; *c*, segments of the root. (After Goebel.)

and have already been considered in the first part of the book.

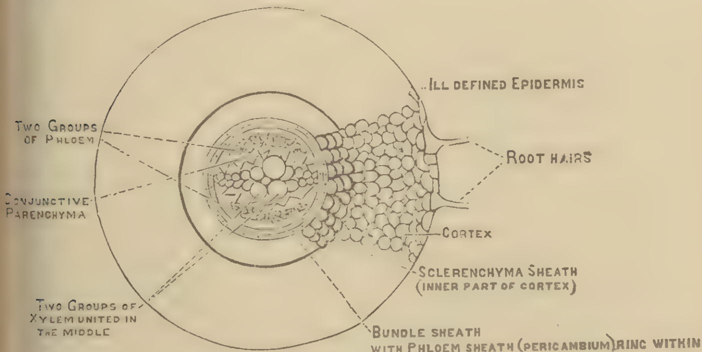

FIG. 122.—Transverse section of older root of fern (× about 50).

Reproduction.—1. Asexual. By the separation and subsequent growth of buds, or by the growth of these bodies into new distinct shoots, without separating from the parent

before so developing. Where a leaf touches damp ground it may bud and produce a new individual.

Sporangia.—On the back of the leaves (*sporophylls*) in summer, *sori* or groups of *sporangia* occur (see Figs. 69, *I*, 120). The sorus contains a number of stalked sporangia, and between these here and there delicate pluricellular hairs (*paraphyses*). The cushion-like projection from the under surface of the leaf, formed below a vascular bundle, to which the sporangia are attached, is the *placenta*, and the expanded roof-like growth from this, covering over the whole, is the *indusium* (Fig. 120).

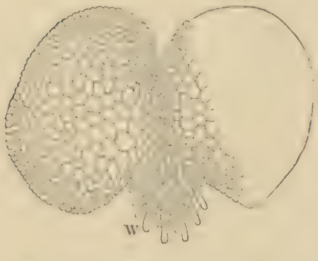

FIG. 123.—Prothallium of *Aspidium setigerum*, × 50. *w*, Root-hairs. (After Behrens.)

The sporangium in this type is a roundish capsule, containing spores, with a long stalk, and the wall of the mature capsule is formed of one layer of cells. A row of these cells, which run round the length of the capsule, are peculiarly thickened and developed, forming a ring of elastic cells known as the *annulus* (see Fig. 69, *II*, *III*). The contraction of the annulus by drying when the spores are ripe, ruptures the sporangium wall, and allows these unicellular bodies to escape.

The sporangium originates in a papilla-like outgrowth of one of the epidermal cells. This is cut off by a cross wall, and after elongation divides transversely, the resulting lower cell, by further (intercalary) divisions, producing the stalk; and the upper cell, the capsule. This latter, the mother-cell of the capsule, divides by four successive oblique walls into four outer cells, which form the outer wall of the capsule (after further divisions), and a tetrahedral inner cell (*archesporium*) that divides into four tabular segments, cut off so as to lie parallel to the outer wall cells. Those tabular segment cells, that subsequently *may* split into two layers, constitute the *tapetum* or temporary storing layer for the spores. The archesporium

cell forms the mother-cells of the spores by successive bipartitions,* and each of the latter, the spores by endogenous (free-cell formation) division into four. When these are being produced and developed the tapetum becomes dissolved up. The walls of the cells that are to form the annulus undergo cross divisions until the proper number of cells in the ring is formed. They then become convex outwards, thicken, and project above the surface of the capsule (see Fig. 69).

Germination of the Spore.—The admission of water causes the contents of the spore to swell and burst the exosporium, and the endosporium protrudes and grows, making a tubular septate filament, in which chloroplasts very soon appear. Soon after a protuberance from the young filament is cut off and forms the first *rhizoid*, and the terminal cells of the filament then divides so as to give rise to a heart-shaped cellular surface (*prothallium*) one cell thick towards the the edges, but several about the middle: on the under surface of this many rhizoids are produced, and the sexual organs (Fig. 123). The growing point of the prothallus lies in the hollow between the two lobes of the heart. The prothallia are sometimes perpetuated by adventitious flat bud-shoots, which spring from or near their margins.

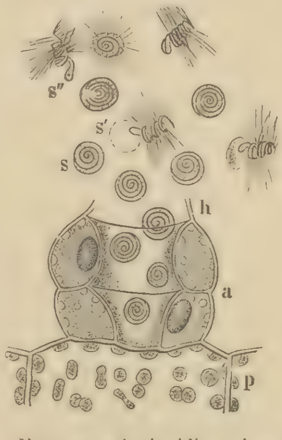

FIG. 124.—Antheridium showing discharge of spermatocytes, *s*; *s′* and *s″* are liberated spermatozoids; one to the right is dragging after it a food-vesicle, containing colourless granules (× 350). (After Behrens.)

2. Sexual.—*Antheridia* may occur on any part of the under surface of the prothallus, and may appear before the latter has reached its full development. *Archegonia*, how-

* Sixteen mother-cells are produced, and each of these dividing into four gives sixty-four free spores.

ever, are found *only* on the cushion (central part) of the under surface of the *fully-developed prothallus.* Both antheridia and archegonia arise from a single cell.

Development of Antheridium.—The cell grows out and divides off as usual at its base. This mother-cell of the antheridium then swells up hemispherically, and divides by an arched or funnel-shaped wall into an upper cell, that by further cross divisions and growth goes to form the wall of the mature organ, and an under and internal cell, called the *central cell.* The latter subsequently divides up to form the *spermatocytes*, or mother-cells of the spermatozoids. The discharge of these bodies from the mature antheridium is due to the rapid absorption of water by the wall cells of that organ, which swell in consequence, and bring about the rupture of the antheridium at the apex (Fig. 124). Then the spermatocytes come forth, and each liberates a spermatozoid (for the origin of which see footnote, page 144).

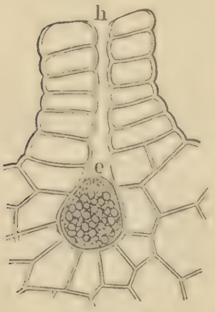

FIG. 125.—Ripe archegonium of *Osmunda regalis.* *h*, neck; *e*, newly-fertilised ovum or oosphere (× 240 times). (After Luerssen.)

Development of Archegonium.—Also proceeds from a superficial cell of the prothallus, which arches outwards and divides into three cells by two transverse walls. The bottom or basal cell, sunk in the prothallus, divides up in the same manner as the surrounding cells of that tissue do, and in conjunction with them contributes to the construction of the *venter* of the archegonium, *which is entirely sunk in the thallus* (Fig. 125). The middle cell forms the *central cell,* and the neck canal cells. The uppermost cell gives rise to the wall or periphery of the neck of the archegonium, the cells at the top of which open when the organ is mature. The central cell divides into an upper *ventral canal cell*, and a lower and much larger *ovum* cell subsequently rounded off and rejuvenated (see Fig. 109).

Fertilisation.—The walls of the neck canal cells become converted into mucilage, and this, together with their protoplasm, is expelled through the opened neck. The

spermatozoids are caught in the mucilage,* and make their way down through the canal to the ovum and fuse with its nucleus; they enter the ovum at a clear spot in it towards the neck (*receptive spot*).

Development of Embryo.—The fertilised egg-cell becomes surrounded with a wall of its own and divides holoblastically † into *octants* by basal, median, and transverse walls. The first, or *basal* wall, which is almost coincident with the axis of the archegonium, divides the cell into an anterior or *epibasal* half, and a posterior or hypobasal half. The latter goes to form the root and the former the stem. A *transversal* wall next forms right through the epibasal and hypobasal cells, at right angles to the basal wall and parallel to the surface of the prothallium. Next, a third wall appears at right angles to the two preceding; this, the *median* wall.‡ These three walls going right through the developing ovum divide it up into eight cells or octants. Of the two *anterior upper* octants (follow all this out on a marble, as recommended in the note below), *one* becomes the growing point of the stem and the other appears to undergo no further differentiation. The *two anterior lower octants* develop into the cotyledon or first leaf. The *two posterior upper octants* go to form the *foot*, which grows a little way into the substance of the prothallus, and constitutes a "nursing" organ for the young plant, absorbing the food required for it from the surrounding cells of the thallus. *One* of the two posterior *lower* octants forms the root, while its neighbour does not differentiate at all. Two walls then appear in the epibasal and hypobasal halves *with the same direction* as the basal wall (get your marble again). One of the four three-sided cells cut off in front by the epibasal wall is the *apical cell of the stem*, and the one opposite in the four corresponding cells, cut off by the hypobasal wall is the *apical cell of the root.*

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* There is malic acid in this mucilage, and this is supposed to attract the spermatozoids in some way. In the mosses the attracting material in the mucilage appears to be cane sugar.

† *I.e.*, completely.

‡ To properly grasp the construction of the embryo at this stage, take a boy's common marble, which will represent the spherical ovum, and mark off round it with a pencil the three walls (basal, transversal, and median) all at right angles to each other. The whole matter will then appear very simple.

By the continued growth and segmentation of the root apical cell, a *primary or tap root* is formed, which, however, dies down latterly, and *secondary lateral* and *adventitious roots* developed from the stem, which becomes a typical rhizome, form the root system of the adult. The apical stem cell forms a primary terminal bud portion (*plumule*), and the continued growth and development of this part gives rise to the mature fern stem and foliage leaves. The primary axial portion developing into primary root and stem is the *radicle*. Each prothallus usually gives rise to only one embryo *which grows into* the adult state: the others become aborted.

Life History.—1. Fern plant (sporophyte): 2. Buds: or fertilised ovum on hermaphrodite (monœcious) prothallus (oophyte). 1. Fern plant or sporophyte.

In general, then, we have a normal regular alternation of sporophyte and oophyte in the cycle of the life history of ferns.

By vegetative propagation, either of the sporophyte or oophyte, the cycle is prolonged, and by *apospory* (*suppression* of spore production) the cycle is shortened. The first case is common to all ferns. Apospory (see page 99) has only yet been observed in *Athyrium Filix-femina* var. *clarissima* * and in *Polystichum angulare* var. *pulcherrinum.** In the *first* named, the prothallia are produced from the vegetative growth of badly developed or immature sporangia, and in the *second* plant they are formed by simple vegetative outgrowths of the tips of the pinnæ.

The life cycle may also be shortened by *apogamy* (disappearance of distinct sexuality; the sexual organs *may* be present but are functionless), only known in some garden varieties (compare with apospory). Apogamy is of various kinds: in one the sexual organs are produced but are functionless, in other cases the sexual organs are not produced at all, or incompletely.† In those cases of apogamy the new plant is produced by the budding of the prothallus, never by *parthenogenesis*, *i.e.*, from the *unfertilised* egg.

* Both are garden varieties.

† On the apogamous prothallia of *Aspidium Filix-mas cristatum*, no archegonia are produced at all.

Prothallia, which in *consequence of* insufficient nourishment cannot produce archegonia, are termed *ameristic*.

Class IX.—Equisetineæ.

The sporophylls, which are peltate in shape, are arranged in whorls, and collectively form a spike (so called) at the end of the stem. The sporangia are borne on the inner surfaces of the peltate sporophylls, and are developed from groups of cells. The spores are all of one kind. There is but one genus (Equisetum).

Equisetum Arvense (Field Horsetail).

The *sporophyte* consists of a perennial rhizome with long internodes, which sends up every year ærial green shoots that usually die down in the autumn. From the nodes of the rhizome, roots and tubular dentate sheaths arise, and the latter also form at the nodes of the ærial stems. The branching is monopodial, and the branches of the shoot arise in whorls and burst through the leaf sheaths at points near their base in the grooves of the stem. The roots are thin and fibrous, and also branch monopodially, and arise in whorls * at the nodes of the rhizome immediately beneath the lateral buds.

Structure of Root. The apex is anatomically in the main quite like that of the fern. A transverse section through an older part shows an ill-defined epidermis with root hairs, beneath this a peripheral outer band of *cortical tissue*, with dark-brown walls, and then, within this, a broad band of colourless *cortex*, with a large annular *intercellular space* † surrounding the *vascular cylinder*, which is bounded or formed on the outside by two rings of cells, first the *bundle sheath* (endodermis?), and within this the *phloem sheath* (pericambium?). These two layers are derived from the innermost layer of the cortex. The vascular cylinder within the phloem sheath consists of *four rudimentary xylem*

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* But at many of the nodes the roots, as well as lateral stem branches, may be partially suppressed.

† At first this is a ring of separate air spaces, which usually afterwards unite by rupture.

groups, and between the arms of these are *four ill-defined phloem groups*, the remainder of the space being occupied by the *conjunctive parenchyma*. The lateral root branches spring from the phloem sheath opposite the xylem.

Structure of Stem.—The outer surface of the ærial stem internodes is striated with longitudinal ridges and furrows,

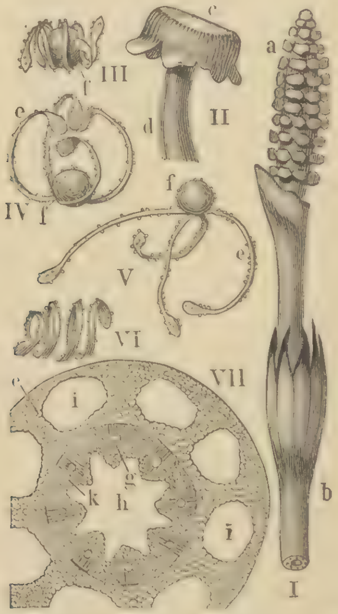

FIG. 126.—*Equisetum arvense.*—I. Fertile stem, nat. size; II. A peltate scale × five times; III.-VI. Spores and elaters, × 200 times; VII. Cross-section of stem, × 10 times. *a*, Spike; *b* Node; *c*, Peltate scale; *d*, Stalk of do.; *e*, Elaters; *f*, Spore. Explanation of VII. in the text. (After Behrens.)

each ridge corresponding to (and continuous with) the apex of a tooth of the leaf sheath. The internal structure has also some relation to these external markings. The vascular bundles, which are arranged in a ring, lie on the same radii as the ridges, and there is a ring of large air spaces in the cortex, each lying internally to the grooves. For the general

structure of the stem, see the transverse section of an internode in Fig. 126, in which, however, the external ridges and grooves are not shown. There is first an ill-defined *epidermis* with stomata, forming, with the subjacent cells, a band of thick walled tissue of variable breadth. Beneath this is a broad band of cortex (*c* in Fig. 126, *VII*) with chlorophyll, at least in the outer part. In this is the *ring of large air spaces* (*i*) already referred to. The cortex is limited internally by a single layer of closely arranged cells (*bundle sheath*, the ring outside the vascular bundles in Fig. 126, *VII*), within which are the vascular bundles (*g*), each alternating with the cortical air spaces. The pith, which lies centrally, is in great measure obliterated by the great central air cavity, *h**; betweeen the bundles (collateral) is ground tissue, *k*. At the node, a thin transverse septum (*diaphragm*) of tissue cuts off the central cavities of adjoining internodes.

FIG. 127.—Showing the mutual forking and fusion of the vascular bundles at the node.

The apex of the stem enclosed in young foliar sheaths culminates in a large apical cell.

Structure of the Leaf Sheath.—1. Epidermis; 2. Mesophyll or ground tissue; 3. One small, simple, vascular bundle in the mesophyll going out to each tooth.

Reproduction.—1. There is a vegetative propagation of the sporophyte by the separation of *tubers*, which are produced at the nodes on the rhizomes.

Sporangia.—The terminal sporiferous spike, with the peltate sporophylls, can be seen in Fig. 126, *I*, *II*. The latter are in whorls, and each bears a whorl of sessile sporangia suspended from the lower surface. The mature sporangium consists of a *wall* one layer of cells in thickness, the cell walls of which are strengthened by a spiral or annular thickening. (The wall of the sac ruptures by a *longitudinal slit* next the pedicle of stalk of sporophyll.) The cavity of the sporangium contains sixty-four *spores*, each of which has spirally-coiled *elaters* (see Fig. 126, *III*) which, when the

* This, as well as the cortical air spaces, is of *lysigenetic* origin (see page 34), as can be observed from the remnants of disorganised cells along the margins.

atmosphere is dry, unwind and assist in discharging the spore (Fig. 126, *IV*, *V*). The spore at first has three coats, from the outermost of which the elaters are formed. The result of the germination of the spore is a lobed prothallus, which is *unisexual*, and produces either antheridia or archegonia.

The *female prothallia* are much larger than the *male*. The antheridia appear embedded in the tissue at the extremity or on the margins of the latter, while in the former, the archegonia are developed on the anterior margins of the fleshy lobes on the upper surface. The archegonia of this type correspond in structure to those of ferns.

Note in this type, the sexual differentiation appearing in unisexual prothallia.

Embryogeny.—The fertilised ovum segments holoblastically and develops in the main as in Aspidium, but there are two cotyledons, the second one being formed from a superior epibasal segment. Those cotyledons, however, do not develop as separate leaves, but unite as they grow with the first leaf of the plumule. The foot is also formed as in ferns, and likewise acts as a nursing organ.

Life History.—1. Equisetum (sporophyte); 2. Tuber; or Fertilised Ovum on female prothallus (oophyte); 1. Equisetum (sporophyte).

Class X.—Lycopodineæ.

The leaves are generally small, simply formed, and numerous. The sporangia are developed from *groups* of cells, and are almost always borne in the axils of leaves, or on the stem above the leaves close to the axil. In Psilotum they occur in groups sunk in the extremities of short lateral branchlets. This class is divided into—*A*. Homosporous Lycopodiaceæ (*Type*—Lycopodium); *B*. Heterosporous Lycopodiaceæ (*Fossil*); *C*. Psilotaceæ (*Type*—Psilotum); *D*. Ligulatæ (*Types*—Selaginella and Isœtes).

Selaginella denticulata.

The sporophyte is a partly creeping and partly upright green shoot, with short internodes, and small simple decussate leaves arranged down the stem in four rows. The branching

is *monopodial* (simulating dichotomy), but the branches are all in one plane, and spring from the sides of the primary axis, and the *dorsiventrality* thus displayed is further brought out by the ventral leaf of each pair being larger than the dorsal. The insertion of the leaf is oblique, and it has a small scale like ligule. True lateral roots are given out from the stem, and near the junction of the lower branches *rhizophores* are also produced. These have the external appearance of roots, but have no root cap. They are intermediate between stems and roots. They are *exogenously*

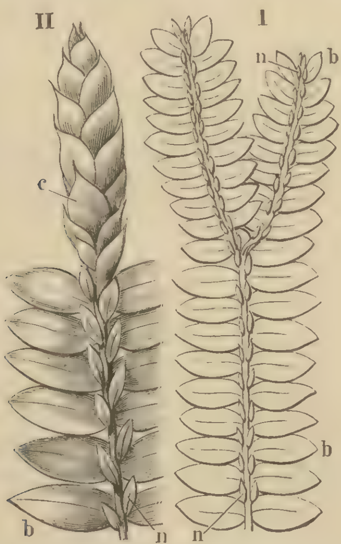

FIG. 128.—*Selaginella pubescens.* I. Leafy twig, × 6 times. II. End of twig, with sporiferous spike *(c)*, × 8 times; *(b)*, Lateral leaves; *(n)*, Ventral leaves. (After Behrens.)

developed, and first grow out a little bit, and then swell into a round shape at the end. The rudiments of true roots are afterwards formed inside the swollen part, and these break through and develop further when the rhizophore, by subsequent intercalary growth, elongates sufficiently to bury its swollen apex into the ground.

Structure of Root.—The apex is the same as that in Fern and Equisetum. The tetrahedral apical cell, however, soon ceases to give off segments, so the elongation is almost entirely due to intercalary growth. The structure of the older part of a root *resembles* that of the rhizophore. In transverse section we find, proceeding from the outside. —*Epidermis*, *cortex*, a somewhat *irregular bundle sheath*, *or endodermis phloem sheath* (pericambium), and within this, forming a central mass, is *one group of xylem* * which is completely *surrounded by the phloem*, except at the point opposite the protoxylem, which is placed laterally.

FIG. 129.—Transverse section of stem of *Selaginella*, showing ill-defined epidermis with cuticle, cortex, central intercellular space with bridges of cells, surrounding young concentric bundle, and produced laterally towards *b* on its way out to a leaf. (After Goebel.)

Structure of Stem.—The apical cell is a two or three sided pyramidal cell. The tip of the shoot axis forms a terminal bud. The origin of the leaves and branches is *not* from a single cell, but from a group of cells at the periphery of the apical cone. The branches are *never axillary*, but arise above one of the ventral leaves. The structure of an older part of the stem is seen in Fig. 129.

* Therefore the root is monarchial.

The vascular bundles of the stem are cauline and concentric * (see pages 47, 49).

Structure of Leaf—Is clearly brought out in Fig. 130.

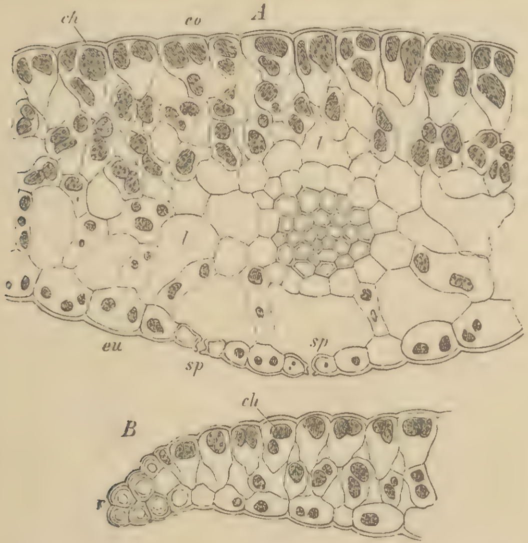

FIG. 130.—Transverse sections through the leaf of *Selaginella inæqualifolia*. *A.* in the middle. *B.* at the margin ; *eo* upper epidermis ; *eu* under epidermis with stomata *sp.* Between *eo* and *eu* is the mesophyll (spongy parenchyma) with large intercellular air spaces *l*, and centrally a single vascular bundle. (After Goebel.)

Stomata only occur on the under surface. They have two guard cells and no subsidiary cells (see page 42).

Reproduction.—1. Asexual. Vegetative propagation is effected by rhizophores, roots, and by the breaking off of the ends of leaves that take root and bud out a new plant. The stem is perennial.

* The most prominent elements of the xylem of Selaginella are spiral and scalariform tracheides, and the principal elements of the phloem are long narrow cells or tubes, with cellulose walls and sparing contents ; these are regarded as the representatives of the sieve tubes of Phanerogams.

Sporangia.—Are shortly stalked roundish capsules, large in comparison with the size of the leaves. They are borne in the axils (one in each) of the leaves (sporophylls) of a special erect fertile branch, forming a so-called terminal sporiferous spike (see Figs. 70, 128). The leaves of this spike are equal in size, and therefore do not exhibit dorsiventrality like the

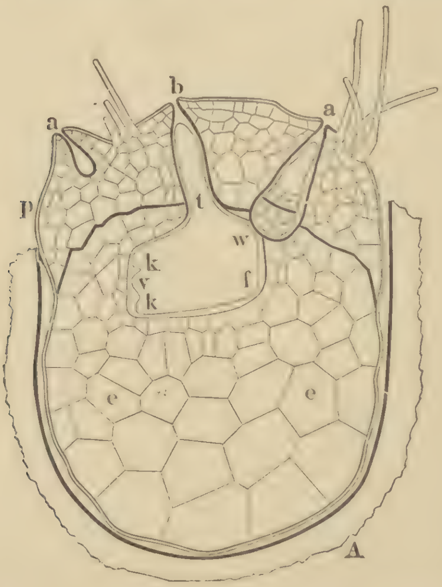

FIG. 131. — Longitudinal section through macrospore of *Selaginella*, showing *p* primary prothallus with archegonia ; *a* and *b*, in which are developing embryos ; *e*, secondary prothallus ; A, wall of macrospore. In the archegonium, *b* ; *t* is the suspensor or pro-embryo, the general body below, the radicle, with *v* the apex of the developing stem, and *k* the leaves ; *v* and *k* together constituting the plumule ; *f*, the foot ; *w*, the primary root end. (After Behrens.)

others : but in phyllotaxis they are similar, and they also have the characteristic ligules. There are two kinds of sporangia, *micro- and macrosporangia*. The sporangium arises from the growth of cells near the base of the leaf in

the tissue of the stem. A hypodermal cell forms the *archesporium*, and the *tapetal layer* is cut off from the surrounding cells. Each cell of the archesporium in the case of the microsporangium divides into four small spores (*microspores*), but in the macrosporangium only one mother cell so divides up, the rest being abortive, and the four spores formed are relatively large, and are known as *macrospores* (megaspores), (see Figs. 70, 71). When the spores are ripe the tapetal cells are destroyed, and the wall of the sporangium then consists of two cell-layers.

Development of Microspores.—After one has fallen to the ground it divides into a very small cell *(vegetative cell* = male prothallus), and a large cell which goes on growing and dividing until it forms an *antheridium*, consisting, when complete, of an outgrowth and four central cells or *spermatocytes.* The nucleus of each of the central cells becomes converted into a *spirally coiled spermatozoid* with *two cilia*, which are formed of the cell protoplasm. By the breaking down of the walls when mature, the spermatozoids escape in water.

Development of Macrospore.—At first this is a single cell with an outer cuticular coat like the microspore, only very much larger. While still yet in the macrosporangium it begins to divide, and these divisions, accompanied by growth, go on after it has been set free and has fallen to the ground, until the whole interior is filled with a cellular tissue or *prothallium.* Certain *superficial*, and first-formed, cells, constituting a sort of *primary* prothallus* in this tissue, now divide up further by a new plan to form one or more archegonia, each with neck and ovum (Fig. 131). The whole endoprothallus continuing to grow, now bursts open the wall of the macrospore at one side, along a triradiate line, and fertilisation follows by the spermatozoids, that are set free about the same time, finding their way into the archegonium.

Development of Embryo.—Soon after fertilisation the

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* Very probably the contents of the macrospore divide first into two cells, one of which moves to the apical side, and there produces the upper or primary prothallus, while the other remains near the base, and gives rise to the main portion or secondary prothallus.

ovum acquires a special wall, grows and divides holoblastically first into two cells, the uppermost of which, by considerable elongation, forms the *suspensor** of the embryo and the latter itself arises from the lower or epibasal cell, of the ovum. By the growth of the suspensor, and the compression and absorption of the adjacent cells, the developing embryo is thrust down ultimately into the secondary prothallium (see Fig. 131—two cotyledons are formed which are not shown in the figure).

In the *alternation of generations* in the life history of *Selaginella* there is, compared with the Fern, a very considerable reduction of the oophyte generation.

Note that sexual differences now appear in the spore and sporangium.

Life History.—1. Selaginella (sporophyte); 2. Propagation by budding; but more commonly by sexual union, the Ovum being the product of an Archegonium on a female prothallus (oophyte), mostly contained within an expanded macrospore. 1. Selaginella (sporophyte).

Class XI.—Gymnospermæ.

This, and the next two classes, Dicotyledons and Monocotyledons (or *one* class—Angiospermæ), compose the division Phanerogamæ or Spermaphytæ, *i.e.*, seed producing plants. The seed is the product of the macrosporangium, or *ovule*, as it is called in Phanerogamæ. (For the parts of the ovule see Figs. 141, 142, 143, and pages 182-184 for description.) The ovum in the embryo-sac or macrospore of the ovule is fertilised by the contents of the pollen tube, which is an outgrowth from the *pollen grain* or microspore. The phanerogamous plant with roots and shoots answers, of course, to the sporophyte of Fern, Equisetum, and Selaginella (vascular cryptogams). In Gymnospermæ the ovules before fertilisation are *not* enclosed in an ovary formed by the cohesion of the margins of *one*, or of *several*, carpels, as is the case in Angiospermæ. A complete *prothallium* (so called endosperm) bearing *archegonia* is produced within, and entirely fills the embryo-sac (macrospore), neither the

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* Suspensor = The row of cells in Phanerogams and Selaginelleæ from the end of which is developed the differentiating embryo.

wall of which, nor the organically connected macrosporangium wall (ovular coats and nucellus), rupture in any wall to allow of the partial exposure of the archegonia as in Selaginellæ. The pollen grain undergoes a few divisions of its contents (as in the ordinary microspore) before the emission of the pollen tube. Class Gymnospermæ is divided into three sub-classes :—

1. *Cycadeæ.*—Stem branching, rare or suppressed ; leaves large and branched. *Type*—Cycas, Zamia.

2. *Coniferæ.*—Abundant axillary stem branching ; leaves small, unbranched. *Types* — Pinus, Taxus, Juniperus, Cupressus.

3. *Gnetaceæ*—This family differs from 1 and 2 in that the male flowers have an investment which more or less resembles the perianth of Angiosperms. *Types*—Welwitschia, Ephedra.

Pinus Sylvestris (Scotch Fir).

The mature plant (sporophyte) is a perennial tree made up

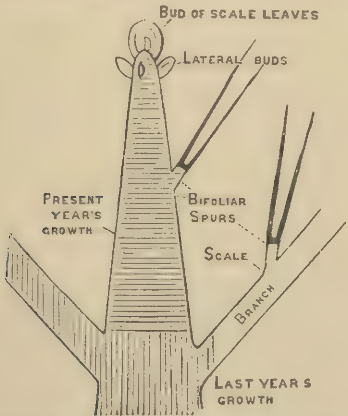

FIG. 132.—Diagram showing external parts of young stem of Pinus

of a thick branched stem, the external portion of which is a rough bark, spirally arranged leaves (scale and foliage), and

a root system composed of a main or tap-root with branches. From the axils of the kataphylls or scale leaves, which are produced all over the plant on the stronger axes of unlimited growth, short branches arise, each of which develops at its extremity two needle-shaped foliage leaves. Those tufts (branch and leaves together) are known as *bifoliar spurs*.

The stronger secondary axes or branches of the first order are developed periodically in terminal rosettes (false whorls), and these in their turn produce similar branches and bifoliar spurs.

Structure of Stem.—The diagrams below sufficiently explain the general structure of this member.

The outline of the stem, at first very irregular, gradually becomes regular by the development in the cortex of a regular periderm. The fascicular and interfascicular cambium arise as in Dicotyledons (see page 52), and secondary

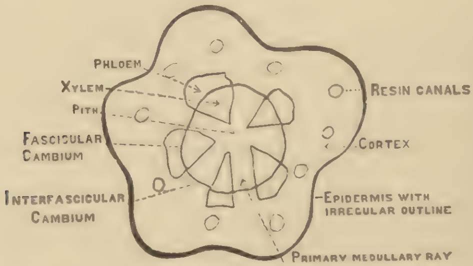

FIG. 133.—Transverse section of first year's stem of Pinus (diagrammatic).

thickening also proceeds as in that class, but the secondary xylem formed here has no vessels, and in fact is composed of one kind of element only, namely *tracheids*, with bordered pits (see Figs. 13, 14). The latter structures are limited to the radial and longitudinal walls. In the more mature stem of the young pine tree, a transverse section beginning at the centre shows us *pith* (very small), medullary sheath or *protoxylem* (first formed xylem next pith), *annual rings of secondary xylem* (each ring showing under the microscope large-celled spring, and small-celled summer and autumn wood, see Fig. 40), a few *primary* and numerous *secondary*

medullary rays passing radially through wood and bast (but not well marked in the latter), minutely microscopic *cambium ring*, with cambiform cells on each side, passing into phloem outwardly and wood inwardly, the phloem consisting of parenchyma and tracheid-like or pointed sieve tubes, with the *sieve plates on the radial walls* like the pits, *cork cambium*

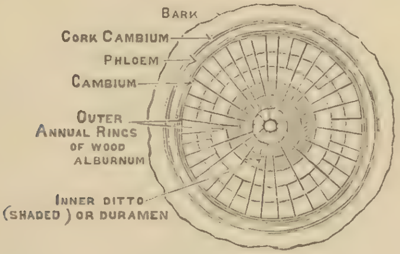

FIG. 134.—Transverse section of six years' old stem of Pinus (diagrammatic). The radial lines extending to the pith are primary medullary, the others are secondary.

irregular ring, and *bark* formed by the activity of the cork cambium (Fig. 134).

Resin canals occur in cortex, wood, and medullary rays. They run longitudinally and also transversely through the plant.

The central portion of the ringed xylem, which is darker in colour than the peripheral part of the same, is called the *duramen* or heart wood, while the latter is the *alburnum* or sap wood. The alburnum is the great carrier of sap through the stem. As it is exogenously increased by the cambium outside, it passes internally into the condition of duramen, the function of which is purely skeletal (Fig. 134).

In Fig. 135 we see the respective appearances presented by medullary rays in transverse, radial, and tangential sections. The ray typically consists of—1. Parenchyma, with protoplasm and starch; and 2. Tracheids, with bordered pits, which are usually external to 1.

Structure of leaf.—The structure of the foliage leaf is shown in Fig. 136.

This kind of leaf is *centric*, because the stomata and assimilating tissue occur all round. In the central clear mass there appear here and there the so-called transfusion cells, which are extensions of the xylem. The foliage leaf

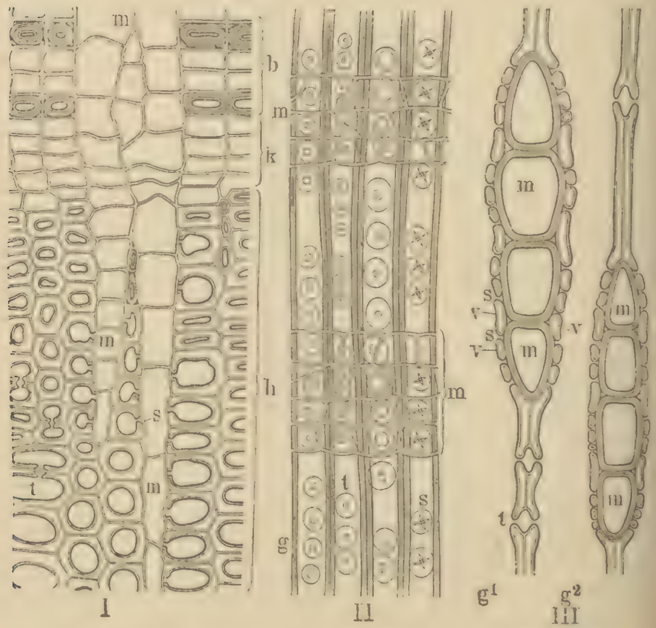

FIG. 135.—I. Transverse, II. Radial, III. Tangential section of the young trunk of *Sequoia gigantea* (giant cyprus), illustrating the medullary rays. *b*, bast; *k*, cambium and cambiform cells; *h*, wood; *m*, medullary ray; *t*, *s*, pits; *g*, *g1*, *g2*, wood fibres; *v*, tracheids of medullary ray (I. and II. × 300 times; III. × 1000 times). (After Behrens.)

lasts two or three years, and when it is shed it is in conjunction with its bifoliar spur (Fig. 132).

Structure of Root.—This is seen in the case of the young root in Fig. 137. The roots, however, increase in circumference, by the formation of a cambium ring, which forms first opposite the phloem groups, and in completing itself

bends outside the xylems and inside the phloems as in Dicotyledons. When secondary thickening is beginning

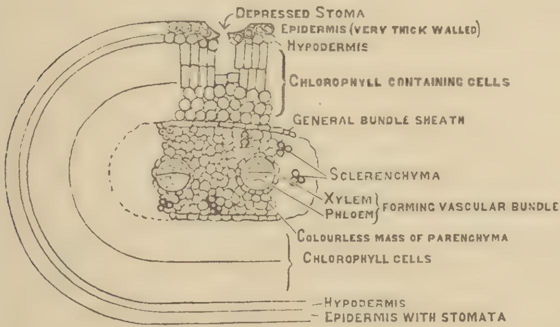

FIG. 136.—Diagrammatic transverse section of foliage-leaf of *Pinus Sylvestris.*

the pericambium, which is often many layers thick, forms a periderm that cuts off all the wide cortex, as in Dicotyledons.

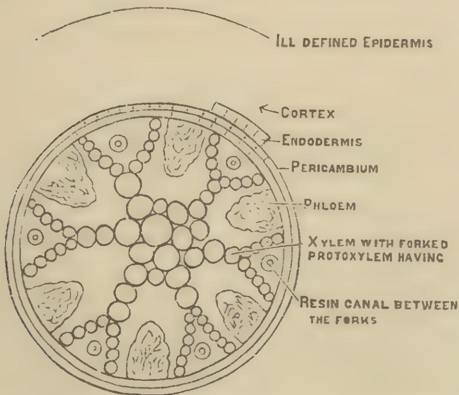

FIG. 137.—Transverse section (diagrammatic) of vascular cylinder of young root of Pinus.

In the apex of the root we have the growing point composed of a *group* of initial cells, which give rise to plerome

(the formative tissue of the vascular cylinder), and a set of cellular strands outside of this representative of calyptrogen (formative of root-cap), dermatogen, and periblem, but these are not marked off from one another. Lateral root branches originate from the pericambium opposite the xylem, as in Dicotyledons. The roots of Conifers appear to have few root hairs, at least of any length, evidently because the transpiration from their leaves is very much less than in Angiosperms; the highly-thickened epidermis and hypoderma, and also the acicular shape of the leaves, tending greatly to keep down transpiration.

Reproduction.—1. There is no vegetative propagation of the sporophyte. 2. Sexual.—The Coniferous flower,* unlike

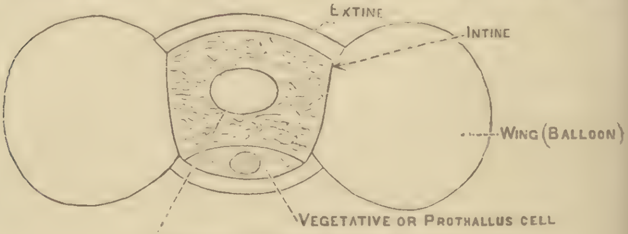

FIG. 138.—Pollen Grain of Pinus (× about 1500 times).

that of the Angiosperm, has an elongated axis, the whole flower assuming the appearance of a *cone.* It is always unisexual and comparatively simple, there being no perianth but only essential organs (stamens or carpels), which latter have a very different structure from those of Angiosperms.

The *male* flower consists of spirally-arranged stamens on a central axis. These male cones or catkins, which occur in clusters, take the place of bifoliar spurs, and are therefore developed upon the lower parts of the annual shoots. Each stamen consists of a scale leaf, which bears two pollen sacs (*Microsporangia*) instead of four, as in Angiosperms (see Fig. 139).

Development of Pollen Sac.—One particular hypodermal cell, with abundant protoplasm, in the line of the axis of

* The Gymnosperm flower is, like that of Angiosperms, a modified shoot.
† Or male gamete, or male pronucleus.

growth, divides up and becomes the archesporium, and further divisions give us the mother-cells of the pollen grains. Round these we get two cell layers formed, the outer the *wall* of the future pollen sac, and the inner the *tapetum*. Each mother-cell subsequently divides into four free pollen grains. At first the pollen grain is a single cell

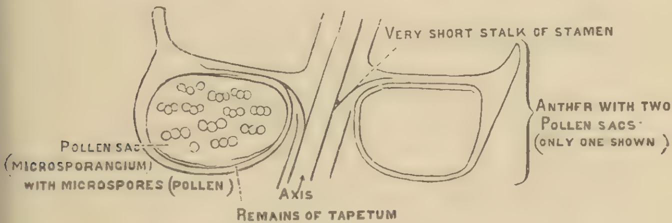

FIG. 139.—Longitudinal section of part of male cone of Pinus.

with an outer cuticular (*extine*), and an inner cellulose coat (*intine*). The nucleus of this, however, soon divides into two, and two cells arise. This is the condition of the grain when it is liberated, and it has also then a pair of balloon-like expansions of the extine filled with air (Fig. 138).

The *female* flower is also an elongated axis, with spirally-

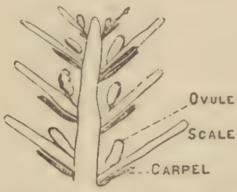

FIG. 140.—Diagrammatic longitudinal section of female cone of Pinus.

arranged leaves (*carpels*) that remain small, but each produces a large outgrowth on the upper surface, which is known as the *ovuliferous* (*seminiferous*) *scale*.* This latter bears two ovules at its base (Fig. 140). The female

* In old cones, generally, only the seminiferous scales are left. The seminiferous scale must be regarded as a placenta of large dimensions, growing out of a carpel leaf.

or macrosporangia cone or spike forms towards the *summit* of annual shoots.

Development of Ovule, or Macrosporangium, and *Fertilisation*.—The ovule originates as an outgrowth on the seminiferous scale.* The nucellus rises first, and then a single integument around it develops, projecting some distance above that body, and forming a broad and comparatively long micropylar canal (see Fig. 141). A hypodermal cell of the nucellus divides, and an embryo-sac mother-cell is formed deep down in the tissue, because of the great development of the primary tapetal cells above, and also of the nucellus. The embryo-sac mother-cell divides into four, the lower cell of which becomes the embryo-sac (macrospore), and the other three get crushed out. The embryo-sac afterwards grows vigorously and becomes very much larger than

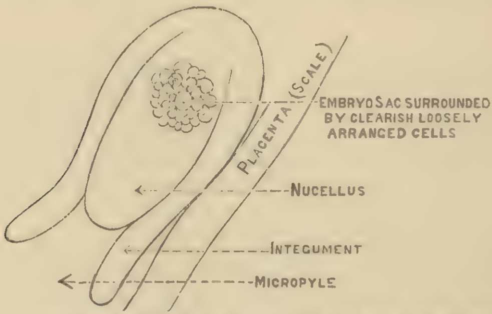

FIG. 141.—Longitudinal Section of ovule of Pinus at time of pollination (Diagrammatic).

its neighbours, but at the time of pollination (in May) it is small, and surrounded with a band of loosely-applied cells (Fig. 141). The pollen blown by the wind is caught in the micropyle by a mucilaginous fluid excreted by the nucellus. This fluid is afterwards gradually absorbed, and the grain stranded on the nucellus. It then germinates and produces a tube (non-septate) from its large cell, which bores a short

* In old cones, generally, only the seminiferous scales are left. The seminiferous scale must be regarded as a placenta of large dimensions, growing out of a carpel leaf.

way into the tissue of the nucellus, and then remains quiescent till the spring of the following year.

The embryo-sac now grows very large, and ultimately occupies almost the whole of the nucellus. While in its first stage of rapid growth its nucleus divides again and again, forming numerous *free* nuclei, and the multiplication of these go on until they fill up all the space (with elbow-room) around the mother-cell wall. They then elaborate cell partitions and walls, and so construct a tissue (endosperm,* or rather *prothallus*), and by ordinary bipartition

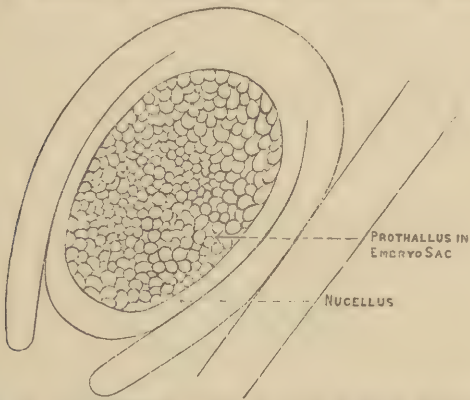

FIG. 142.—Longitudinal section of ovule of Pinus about a year after time of pollination.

extend it inwards so as to fill up the whole embryo-sac. The appearance of the ovule at this stage is shown diagrammatically in Fig. 142.

Certain cells of this prothallus, or so called endosperm, lying near the micropyle end, and separated from each other by narrow bits of intervening tissue, now grow very much larger than their neighbours, and cut off from their micropyle end a small cell. These (large and small cell together) are the beginnings of *archegonia ;* the upper small cell dividing to form the short *neck*, and the lower or *central cell*,

* The *true* endosperm, that of the Angiosperms, forms after fertilisation. The so-called endosperm of Pines is really a prothallus which is produced by the germination? of the contents of the macrospore inside the macrosporangium.

or *ovum*, remaining undivided (after it has cut off the little ventral canal cell) till after fertilisation (Fig. 143).

By the time the ovule has advanced to this stage, a year from the period of pollination has elapsed; and the pollen tube, after its twelve months' rest, now begins to grow again, and goes on elongating and boring its way through the nucellus until it reaches the embryo-sac wall, over one of the archegonia. It then proceeds, by further growth, down, or rather up, between the neck cells to the ovum. Division of the ovum nucleus now occurs, and one of the two nuclei produced goes over into the pollen tube and fuses with the generative nucleus there; the fused, or conjugated pair, then come back into the ovum. (This view is not commonly held: Professor Balfour states that the generative or male pronucleus goes right through into the ovum and fuses *there*

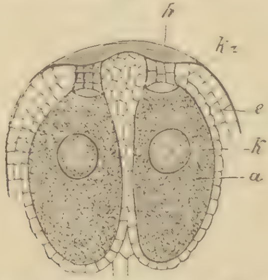

FIG. 143.—Apical part of embryo-sac of *Picea* with two mature archegonia; *a*, central cell of archegonium with its nucleus, *k*; *kz*, canal cell; and *h*, neck of archegonium; *e*, prothallium.

with the female nucleus or gamete. It in the end comes to be just six and half-a-dozen).

The *germ nucleus*—as the nuclear body resulting from the coalescence of the male and female pronuclei is called—now moves to the bottom of the ovum and divides there, after that structure has acquired a special wall of its own, and has begun again to grow, forming two and then four cells, which afterwards divide by tranverse walls into three tiers, one above the other.* The cells of the upper tier remain fixed

* Note that the whole ovum does not completely divide as is the usual rule in plants, but segments in a partial or *meroblastic* fashion, the upper part acting as an organ of reserve food for the proembryos (Fig. 114, *d, f*).

in the archegonium ; the cells of the second, or middle tier, develop into long sinuous tubes (*suspensors*), carrying at their ends the cells of the first, or lower tier, which they thrust well into the prothallium, now regarded as a secondary endosperm, being a storehouse of food for the developing embryos. Each of these end cells gives rise to a distinct embryo. *Polyembryony* is the rule in Conifers because there are several archegonia * in each embryo-sac, and each of these, as in Pinus, may give rise to four embryos; but only one embryo in general becomes fully developed.

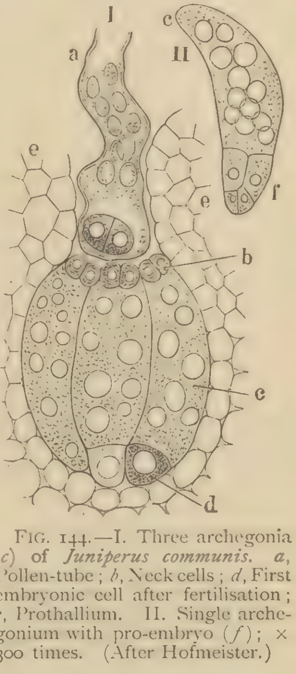

FIG. 144.—I. Three archegonia (*c*) of *Juniperus communis*. *a*, Pollen-tube ; *b*, Neck cells ; *d*, First embryonic cell after fertilisation ; *e*, Prothallium. II. Single archegonium with pro-embryo (*f*) ; × 300 times. (After Hofmeister.)

In the young proembryo then, there are the lower cells, rich in protoplasm, forming the *rudiment of the embryo proper*, and the suspensor (Fig. 145). The differentiation of the root, while the development of the rudimentary embryo is proceeding, commences at some depth in its tissue. Tangential divisions first occur in a layer of cells arranged in a half circle, with convexity next the suspensor (*ws* in Fig. 146), and surrounded on all sides by the tissue of the developing embryo, so that the first rudiment of the root has from the beginning a very considerable root cap (*wh*); *v*, in Fig. 146, is the apex of the embryo stem (which by growth becomes the main stem of the adult), and the cotyledons originate close beneath it.

During the maturing of the ovule the tubular cells of the

* There are three to five archegonia in each ovule of Pinus, and each, as detailed above, produces four proembryos.

suspensor disappear. It takes another year after fertilisation to produce the seed, which is defined as a *mature sporangium* containing an embryo with a certain amount of food reserved for nourishment at the time of germination.

The *Seed* of Pinus consists of—1. Testa, prolonged into a wing at one part; 2. Nucellus (very thin dried layer); 3. Endosperm (secondary); 4. One fully developed, and a number of rudimentary embryos.

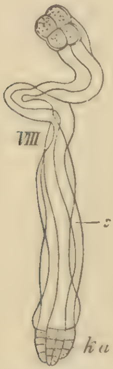

FIG. 145.—The Proembryos of Pinus. *s*, suspensors; *ka*, the rudiments of the embryos. (After Goebel.)

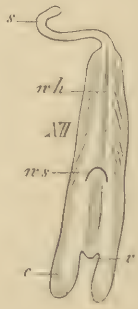

FIG. 146.—Formation of the embryo in *Pinus pumilio* (× 12). *ws*, the apex of the root; *wh*, the root-cap; *c*, the cotyledons; *v*, the growing point of the stem; *s*, the suspensor. (After Strasburger.)

Germination.—The tip of the root first protrudes through the bursting seed coat, and then by the rapid growth in length of the bases of the cotyledons, the plumule (bud at apex of stem) is thrust forth. The upper portions of the cotyledons, however, remain in the secondary endosperm (prothallus full of food) until they have gradually transferred all the food into the expanding plantlet. After they have done this they come out, are carried up above ground, and act as the first foliage leaves (*epigeal* cotyledons).*

* The cotyledons of Pinus develop chlorophyll while yet in the seed.

Life History.—1. Pinus; 2. Fertilised Ovum in archegonium in prothallus, which is produced within the macrospore (embryo-sac) that remains within the macrosporangium (ovule). 1. Pinus.

Note the reduction of the oophyte (vegetative cell or prothallus of pollen grain, and prothallus of embryo-sac) and its concealment, and the sexual differentiation appearing in the sporophylls.

Note.—In Pinus each pollen tube fertilises only one archegonium, bu in the Cupressineal (another family of Coniferæ) one tube is sufficient for the whole group of archegonia (see Fig. 144).

Division Angiospermæ.

Ovules enclosed in an ovary. No *prothallium* bearing archegonia is produced within the embryo-sac, but three naked cells (constituting a rudimentary archegonium) are formed at the apex of the sac before fertilisation, and one of these is the ovum (Fig. 73). A true endosperm (a storing tissue outside the embryo for the benefit of the latter) is formed before fertilisation in the embryo-sac (page 97). The Angiosperms exhibit a high degree of metamorphosis in the flower shoot.

Class XII. Monocotyledons.

Embryo has one cotyledon and is usually small, and there is generally a large amount of endosperm in the seed. The

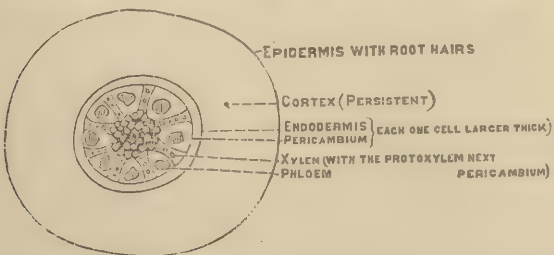

Fig. 147.—Diagrammatic transverse section of root of Scilla.

primary or tap root soon ceases to grow, its place being taken by lateral roots developed from the stem. The stem, as a rule, has no secondary thickening; its vascular bundles are scattered and definite, or closed. The veins of the leaves

almost always run parallel or in regular curves. The flower parts are arranged in three's, or multiples of three.

Scilla Nutans, or Wild Hyacinth (Type of Monocotyledon belonging to the order Liliaceæ).

The Sporophyte.—The shoot begins as a *tunicated bulb* (see page 59), and perennation is effected by a new bulb being annually formed from the side of the old one. Frequently, by an increase in the number of bulbs produced we get vegetative propagation. The stem grows up through the bulb, and rootlets, which pierce the mucilaginous coat of the preceding year's bulb, are given out from the stem. The top of the mature stem becomes a flower axis, and the inflorescence produced on it is a simple *raceme* (see page 65). There are both scale and foliage leaves. The former constitute the greater part of the bulb. The latter are long, narrow, and green, with parallel venation.

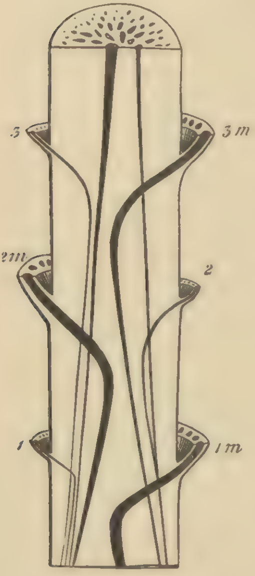

FIG. 148. — Longitudinal section through the axis of a Monocotyledon stem, showing a transverse section of half of it. The leaves (cut off above the insertion) are hypothetically conceived of as distichous and amplexicaul, and so are seen on both sides of the stem, *m*1 *m*2 *m*3 being the median line of each. (After Prantl.)

The Root Structure.—See Figs. 147, 150.

The roots of the Monocotyledons are generally polyarchial, *i.e.*, have relatively many xylems and phloems. The endodermis, and even pericambium, may become much thickened, also the conjunctive tissue (that within the pericambium, but not of the vascular bundles). The exodermis (layer below the epidermis) forms the permanent protective layer of the older roots. The lateral roots arise, as in Dicotyledons, opposite the xylems.

(In grasses, generally, they come from the pericambium opposite the phloems).

Structure of Stem.—See Figs. 148, 149.

Structure of Leaf.—Fig. 151 shows the structure of the foliage leaf. A section through one of the fleshy scales of the bulb would show the same general arrangement, but the parenchyma would be quite undifferentiated, colourless, much more bulky, and densely stored with starch.

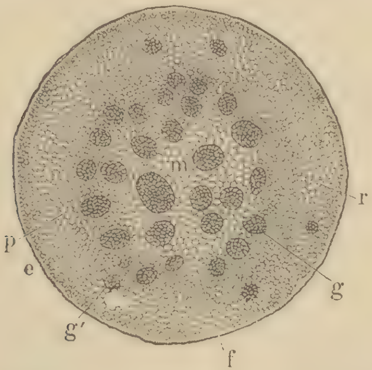

FIG. 149.—Transverse section of Monocotyledon stem; *e*, Epidermis; *p*, *r*, *m*, Parenchyma of the ground tissue; *g*, scattered vascular bundles. (After Behrens.)

The *Flower* is stalked, and originates in the axil of a leaf *(bract).* It is complete, regular, superior, and hermaphrodite. The pollen is carried by insects. For the structure of stamen, ovary, ovule, fertilisation and development of embryo, see next type (Helianthus), with which it agrees, except on the following points:—The endosperm is not used up *before* the germination of the seed, and the embryo develops only one cotyledon. The fruit is a capsule.

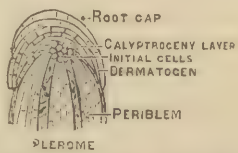

FIG. 150. — Longitudinal section, apex of root of Scilla (diagrammatic.)

Life History.—Same as Helianthus.

Class XIII.—Dicotyledons.

Seed usually with, but frequently without, endosperm. The occasional absence of this tissue is due to its displacement by the rapid growth of the embryo before the seed reaches maturity. The embryo has almost always two

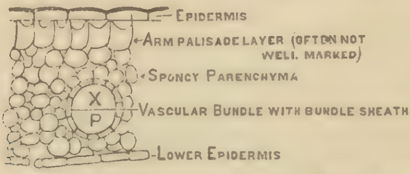

Fig. 151.—Diagrammatic transverse section of foliage-leaf of Lily.

cotyledons. A main or tap root system is developed. The stem has *open* vascular bundles arranged in a ring. The venation of the leaves is usually reticulated, and the flower parts are in whorls of fives or fours.

Helianthus Annus, or Sunflower (Type of Dicotyledon belonging to the order Compositæ).

Sporophyte.—The main stem is erect, stout, herbaceous, cylindrical, hairy, with few branches usually. There is a tap-root system. The leaves are petiolate, simple, pinnate; their arrangement in the lower part of the plant is opposite, or whorled, in the upper alternate. The flowers are small, and arranged in a dense head or *capitulum* (see page 66).

Structure of Stem.—The vascular bundles are *common*, as in flowering plants generally, and therefore their arrangement depends on the arrangement of the leaves, and *vice versâ*. They join and separate here and there as they run through the stem. All the structural parts of the plant are derived, of course, from the initial cells at the apices of stem and root. From these growing points strands of cells are formed, which run in the outer part of the plerome. These special strands are termed procambium. When traced down the stem they are seen to pass into vascular bundles. (All vascular plants have procambium strands). The

diagram in Fig. 152 shows how the procambium passes into the vascular bundle in Dicotyledon and Gymnosperm stems.

The portions of the xylem and phloem first formed in these strands are called respectively *protoxylem* and *protophloem*.

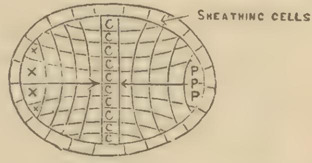

FIG. 152.—Showing progress of change of Procambium bundle into vascular tissue. *X* are the first cells to change into wood, and *P* the first into bast. Then the course follows the arrows until *C* is reached, which *retains* the meristem character, becoming cambium, and therefore making the bundle an *open* one. In other vascular plants, except Gymnosperms and Dicotyledons, *C* is also entirely changed into wood or bast, the bundle becoming *closed*.

The vessels are the most characteristic structures in the wood. In the protoxylem they are either *spiral* or *annular*, in all secondary xylem almost always *reticulated*. The other elements of the xylem are *prosenchyma* (strengthening) and *parenchyma* (storing to a certain extent). The true or soft bast consists of sieve tubes, with their companion cells, and parenchyma (Figs. 30, 32). There is a hard prosenchymatous tissue (so-called hard bast) outside the true bast in this type (the light-shaded outer portion of the bundles in Fig. 153). The greater part of the ground tissue of the sunflower stem is paren-

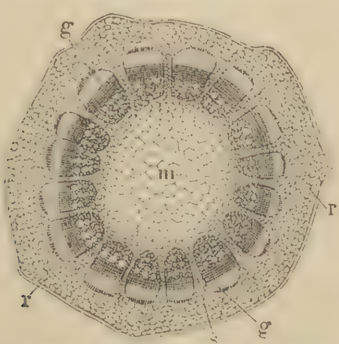

FIG. 153.—Transverse section of stem of typical Dicotyledon (× 15 times). *e*, epidermis; *r*, cortex; *m*, pith; *g*, vascular bundles; *s*, primary medullary. (After Behrens.)

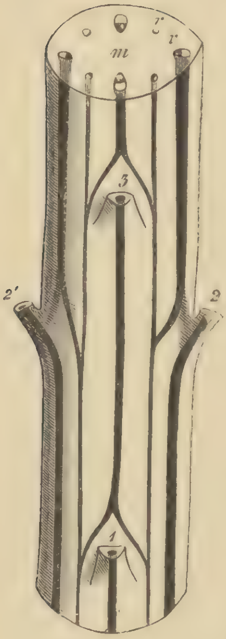

FIG. 154.—Outside view and transverse section of Dicotyledon stem (hypothetically transparent to show the internal bundles). The decussate leaves are cut off. The bundle proceeding from each leaf divides into two above the leaf immediately below it, and the branches of all the bundles unite to form the four thin bundles which alternate in the section with the thicker ones. In the section, *m* is the pith; *r*, the cortex; *v*, the medullary ray. The xylem in the fibro-vascular bundles is indicated by shading. (After Prantl.)

chyma. The outer part of the cortex is often modified to form *collenchyma* (see page 37).

The increase in thickness is primarily brought about by the regular increase of wood and bast, by the formation of a *cambium ring* (see page 52), the *interfascicular* cambium arising in the primary medullary rays by "infection"? due to the divisional activity of the *fascicular* cambium between the primary bundles.

The Foliage Leaf.—

1. Development.—The *base* is first formed (*bud scales* reach no higher stage of development than this), then there arises on the end of it the *lamina* or blade, and finally the *petiole* is developed by intercalary growth between base and blade. The lamina develops *basipetally* (Fig. 20).

2. Structure.—See the diagrammatic section, Fig. 156, 159. The vascular bundles in the leaf are closed. The terminating portion of the fine vein branches in a leaf is xylem. The palisade tissue has most of the chlorophyll. The spongy parenchyma is the tissue of transpiration pre-eminently, the palisade of assimilation. When the chlorophyll cells are exposed direct to the rays of the sun, the plastids arrange themselves end on in the condition of *apostrophe* (Fig. 157). When, however, the cell is exposed to diffused daylight, the plastids spread out on the top and bottom sides, so as to get as much light as possible (Fig. 158). The palisade

cells in the daytime are in apostrophe, and the spongy parenchyma in epistrophe.

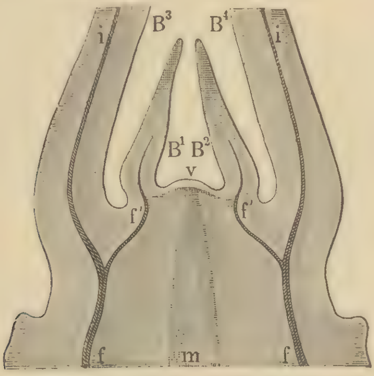

FIG. 155.—Section across the tip of the Stem of a Typical Dicotyledon × 50 times. *v*, growing plant; *B*1, *B*2, *B*3, *B*4, the two youngest pairs of leaves; *f*, *f*, *i*, *i*, vascular bundles of the second youngest; *f*1, *f*1, vascular bundles of the youngest; *m*, pith or medulla. (After Behrens.)

The *fall of the leaf* is brought about in one of two ways. —1. By growth of cells at its base, which part with their middle lamella (see page 33 and Fig. 3). 2. By periderm, which forms right along the stem at and through the insertion of the leaf. Before the fall, however, all the protoplasm and plastids are absorbed into the stem.

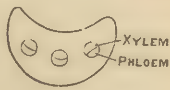

FIG. 156.—Section of Petiole.

Structure of Root.—Quite like that of Scilla (see Figs. 147, 150), but the number of xylem bundles

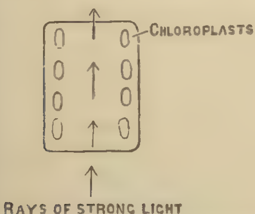

FIG. 157.—Apostrophe Condition.

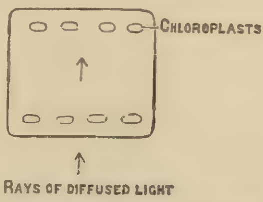

FIG. 158.—Epistrophe Condition.

is less (four very common). Secondary growth in thick-

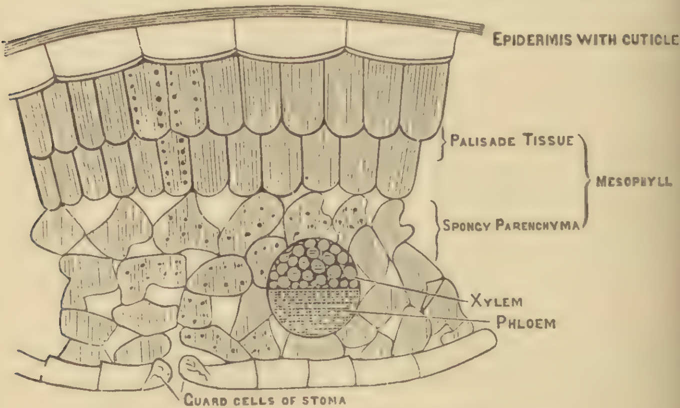

FIG. 159.—Transverse section of Leaf of Sunflower.

ness takes place as in Pinus. The cortex gets cut off by the pericambium forming periderm.

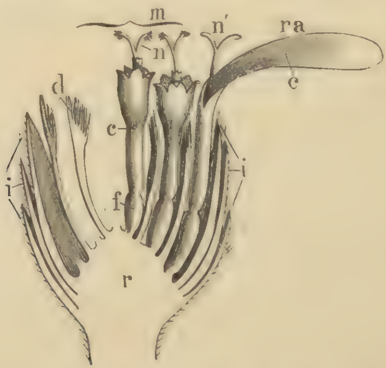

FIG. 160.—Longitudinal section of Typical Capitulum. *r*, receptacle (axis of inflorescence); *i*, involucre; *d*, bracteoles; *ra*, floret (female) of the ray with (*c*) its ligulate gamopetalous corolla, and (*n'*) its style with two stigmas; *m*, florets *hermaphrodite* of the disc with (*f*) inferior ovary; *c*, gamopetalous regular corolla; *n*, styles with hairy stigmas rising up out of a cylinder formed by the coherent edges of the anthers. (After Prantl.)

Inflorescence.—The flowers of *Helianthus* are arranged in a close head or capitulum (see page 66), as shown in Fig. 160.

The stamens are ripe before the pistils of the *same* inflorescence in *Helianthus*, therefore the flowers are said to be proterandrous. The object of proterandry is to prevent self-fertilisation.

The Stamen.—Has two parts, *filament* and *bi-lobed anther.* Development of Anther.—At first is a mass of homogeneous meristem, then outline of anther lobes are formed, united

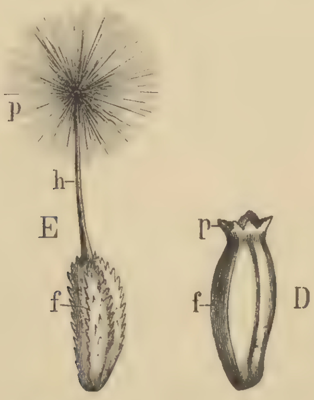

FIG. 161.—D, Fruit (achene) of Tenacetum, with a scaly pappus (calyx), *p*.
E, Fruit of Taraxacum, with a hairy pappus, *p*.

by connective. In *each* lobe two strands or rows of cells apart from each other divide up, and ultimately we get four *archesporia*, each surrounded by a *tapetal* lining, which soon becomes completely disorganised. The archesporium or central cells are afterwards isolated by growth, and then become mother-cells of the pollen; each giving rise to the latter by endogenous division into four, as in the case of the mother-cells of other spores.

Pollen Grain.—Is a single cell with the two coats usual to spores. Its nucleus divides into two, one *big* and one

small nucleus ; the *latter* being the *generative nucleus* (male pronucleus), the former the *vegetative nucleus* (compare with Pinus). The pollen conveyed by insects germinate on the stigma of the pistil or female organ, which has a velvety or papillose surface that, when mature, excretes a sugary solution. The pollen grain absorbs the solution, bursts its extine at a weak place, and protrudes its intine, growing as a tube, which dies off behind as it elongates in front, the protoplasm within the male gamete always keeping at the growing end of the tube. The pollen tube passes or eats its way down the style into the ovary, and through the micropyle and nucellus of the ovule, and in between the projecting cellulose wall portion of the synergidæ (see page 95 and Figs. 72, 73).

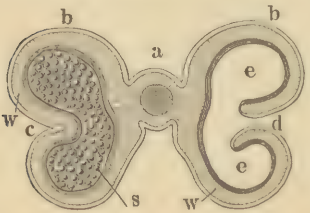

FIG. 162.—Transverse section of the anther of fritillary *Fritillaria imperialis* × 15 times. *a*, filament; *b*, *b*, anthers; *c*, suture; *d*, slit; *e*, internal cavity of the anther; at *s*, filled with pollen; *w*, outer wall (somewhat diagrammatic).

Development of Ovule.—The ovary of this type contains only one ovule (anatropous) which arises, as previously explained by the outgrowth of part of the surface of the placenta, the nucellus originating first as a papilla, and the concentric coats (two) springing up around it shortly afterwards.

Development of the Embryo Sac in Ovule.—One cell in nucellus divides into two: the upper is the tapetal cell, which is soon knocked out of distinguishable existence, and the lower (archesporium) becomes the embryo-sac, by great continued growth and internal development, as follows:—

When the embryo sac is much larger than the surrounding cells, but still growing, its nucellus divides up, and we get an egg apparatus at the micropyle end, consisting of a naked *ovum*, with two only partially-walled *synergidæ*, as explained on page 96.

Impregnation.—The generative nucleus of the pollen tube, when it has got in between the synergidæ, goes over to the ovum and fuses with its nucleus. The fertilised

ovum* now surrounds itself with a cell-wall, and begins again to grow and divide transversely, forming a proembryo and embryo (see Fig. 74). When these are being produced, endosperm tissue, which ultimately fills the whole embryo sac (also growing in size at this time), is developed (see page 97), and persists till the germination of the seed.

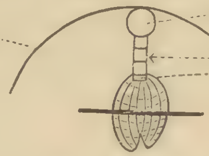

FIG. 163.—The Developing Embryo.

Life History.—1. Helianthus (sporophyte); 2. Fertilised Ovum in Embryo Sac. 1. Helianthus.

Note.—The reduction to a most rudimentary condition of the distinct oophyte† and its concealment in the production of seed.

Ulmus Montana (Scotch Elm).

A fine example of a deciduous Dicotyledon tree. It has, when mature, a thick branched main stem covered by rough bark, and the green terminal twigs have green *bifacial* leaves (compare with *Pinus*), each having one bud in its axil. There is a tap root system. The structure of the young stem, root, and leaf is practically the same as Helianthus, and, of course, the functions are similar. In the mature stem *all* the rings of wood contain large vessels (compare with *Pinus*). There is no vegetative reproduction. Pollination is effected by the agency of wind. The axillary flower clusters appear in spring on the one-year-old twigs before the foliage leaves unfold

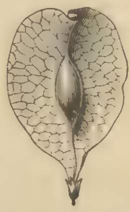

Fig. 164.—Winged nut of elm (*Ulmus Campestris*). (After Behrens.)

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* The synergidæ soon disappear, *i.e.*, become completely disorganised.

† Male oophyte (vegetative nucleus in pollen grain), Female oophyte (so called) antipodal cells in embryo sac. See Fig. 73.

from the bud. The flower is hermaphrodite, and has four to six perianth segments, five stamens, a superior ovary composed of two coherent carpels with a solitary pendulous inverted ovule inside. The germination of the spores, *micro* and *macro*, proceed as in Helianthus; the process of fertilisation also is similar, and so is the development of the embryo, only the latter continues to grow for some time after formation in the ovule, and takes in all the material of the endosperm, storing it up in the body of its cotyledons. The seed is, therefore, exalbuminous (see page 70). The fruit is a winged achene or *samara* (see Fig. 164).

Life History.—As Helianthus.

Summary of Important Points of Difference between Gymnosperms and Angiosperms.

Gymnosperms.	*Angiosperms.*
1. The *male* flower (at least) is a kind of *cone*, *i.e.*, has a prolonged axis on which the numerous sporophylls are inserted.	1. The floral axis is contracted.
2. *Ovules* naked, *i.e.*, not enclosed in an ovary.	2. The *ovules* are in an ovary.
3. A tissue *(prothallus)*, functionally the same as endosperm, fills the embryo sac, and produces the female apparatus (archegonia).	3. The female or egg apparatus is not produced on a prothallus, and true endosperm forms after fertilisation.
4. Usually *polyembryonal.*	4. *Not* polyembryonal.

Comparative Homologies.

Male Homologues.—The Stamen of Phanerogams is the Sporophyll or leaf which bears the Pollen sacs.

1. The *Microsporangium* of higher Vascular Cryptogams corresponds to the *Pollen Sac.*

2. The *Microspore* corresponds to the *Pollen Grain.*

3. The *Male Prothallus* of higher Vascular Cryptogams corresponds to the *Vegetative Cell*, separated off more or less completely in the pollen grain.

4. The *Antheridium* of Cryptogams corresponds to the *Pollen Tube.*

5. The *Spermatozoid* of Cryptogams corresponds to the *Generative Nucleus* in the pollen grain or tube.

Note.—The *generative nucleus* of Phanerogams is practically *passive*, while that of Cryptogams in the condition of *spermatozoid* is eminently *active*.

Female Homologues.—The *Macrosporangium* or Megasporium of the higher Vascular Cryptogams corresponds to the *Ovule* of Phanerogams, and the *Sporophyll* of the Macrosporangium to the *Carpel*.

1. The *Macrospore* (Megaspore) corresponds to the *Embryo Sac*.
2. The Female Prothallus of the higher Vascular Cryptogams corresponds to the *Female Prothallus*, or so-called Endosperm of *Gymnosperms*, and to the *Antipodal Cells* of *Angiosperms*.
3. The *Archegonium* of Cryptogams corresponds to the Archegonium of *Gymnosperms*, and to the *Egg Apparatus* (Ovum and Synergidæ) of *Angiosperms*.

SIXTY-SIX NATURAL ORDERS OF ANGIOSPERMÆ.

CLASS I.—DICOTYLEDONES.

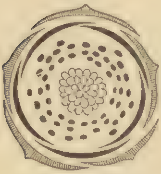
SUB-CLASS I.—POLYPETALÆ.

Section A.—*Hypogynæ* (*Thalamifloræ*).

RANUNCULACEÆ.

St.* *indefinite*, Gn. *apocarpus*. (Syncarpous in Nigella).

Fruits. — Achene, Follicle, Berry (*Actæa*), Capsule (*Nigella*).



Ranunculus.

BERBERIDEÆ.

St. 6 (24 in *Epimedium*) *with valvular dehiscence.*

Fruits.—Berry, Capsule (*Epimedium*).

Berberis.

NYMPHÆACEÆ.

Aquatic. St. *and Petals indefinite.* Pistil apo- or syncarpous.

Fruit. — Capsule or Berry.

Seeds usually with both endosperm and *perisperm.*

Nymphæa.

HYPERICINEÆ.

St. *Polyadelphous*, and apparently *indefinite.*

Fruit.—Capsule.

Seeds.—*Exalbuminous.*

Hypericaceæ.

MALVACEÆ.

St. *monadelphous*, and apparently *indefinite*, *with the corolla adnate to their base. Ovary multilocular.*

Fruit.—Schizocarp.

Malva.

TILIACEÆ.

Leaves oblique, with deciduous stipules. St. apparently *indefinite.* Inflorescence Cymose. *Peduncle adnate to leafy bract.*

Fruit. — Achene or Berry.

Tilia.

* In this and the following pages St. = Stamens, and Gn. = Gynœcium or Carpels.

SUB-CLASS I.—POLYPETALÆ—*continued.*

Section A.—*Hypogynæ* (*Thalamifloræ*)—*continued.*

PAPAVERACEÆ.

St. *indefinite*, Gn. *syncarpous*. *Placentas parietal.*

Fruits.—Capsule (Siliquose in Celandine). *Æscholtzia*, a common garden annual, has a *perigynous* flower.

Papaver.

CRUCIFERÆ.

Petals 4. St. *tetradynamous*. Very rarely 2 or 4 St. are undeveloped.

Fruits. — Siliqua or Silicula (Lomentaceous Siliqua in Radish; one-seeded and *indehiscent* fruit in *Isatis*).

Capsella.

RESEDACEÆ.

Petals *palmatifid*. St. *indefinite on a lateral disc*.

Fruit.—Capsule.

Seeds.—*Exalbuminous.*

Reseda.

LINACEÆ.

Slender. All the parts of the flower in 5's.

Fruit.—Capsule.

Linum.

GERANIACEÆ.

All the parts of the flower in 5's.

Fruit. — *Schizocarp* septicidal from below upwards. Ovary *prolonged into a beak* after maturity.

Seeds.—*Exalbuminous.*

Geranium.

RUTACEÆ.

Strongly scented. Leaves with oil-glands. St. as many or twice as many as petals (indefinite in *Citrus*).

Fruit. — Capsule, Schizocarp, or Berry.

Dictamnus.

SUB-CLASS I.—POLYPETALÆ—*continued.*

Section A.—*Hypogynæ* (*Thalamifloræ*)—*continued.*

VIOLACEÆ.

Flower *irregular, spurred.* Sepals *peltate.* St. 5, *with produced connective.* Ovary *with* 3 *parietal placentas.*

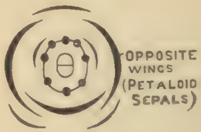
Fruit. — Capsule. *Cleistogamous* flowers appear in this order.

Viola.

POLYGALACEÆ.

Flower *irregular.* St. 8 *monodelphous.*

Fruit.—Capsule.



Polygala.

SAPINDACEÆ.

Flower usually *obliquely irregular.* St. 7 *of unequal length.* Ovary 3-*chambered.*

Fruit.—*Dehiscent* fleshy Capsule.

Hippocastanum.

CARYOPHYLLACEÆ.

Leaves *opposite.* Nodes *swollen. Definite* inflorescence. Placentation *free central.*

Fruit.—Capsule.

Stellaria.

SUB-CLASS I.—POLYPETALÆ.

Section B.—*Perigynæ.*

ILICINEÆ.

Indigenous species has evergreen coriaceous spinous leaves. St. 4 *to* 6. 1 or 2 *suspended ovules* in each loculus. Corolla *may be* gamopetalous.

Fruit.—Berry.

Ilex.

LEGUMINOSÆ.

Corolla of British species, *papilionaceous.* St. in British species 10, *monadelphous* or *diadelphous.* Ovary *of a single carpel.*

Fruit. — *Legume* or *lomentum.*

Seeds.—*Exalbuminous.*

Laburnum.

SAXIFRAGACEÆ (Proper).

St. *equal or double the number of petals.* Syncarpous ovary composed of 2 *carpels diverging above.*

Fruit. — Capsule. (Compare with Parnassieæ, Hydrangeæ, Philadelpheæ, Ribesiaceæ.)

Saxifraga.

RHAMNEÆ.

Shrubs. St. *opposite to the petals.*

Fruit. — Drupe or Capsule.

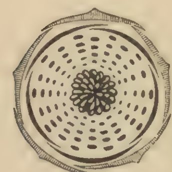
Rhamnus.

ROSACEÆ.

Flower *regular.* St. *indefinite* (or rarely 4). Gn. *apocarpous,* or spuriously syncarpous when the ovary is adherent to the receptacle (Apple).

Fruits. — Achene, Follicle, Drupe, Pome.

Seeds.—*Exalbuminous.*



Rosa.

LYTHRACEÆ.

In European species calyx is tubular and strongly ribbed; the petals spring from below the sinuses of the calyx, and St. are inserted on calyx tube below attachment of the petals.

St. 4–16 in whorls, according to number of petals. Ovary *free in the hollow receptacle and bilocular.*

Fruit.—Capsule.

Seeds.—*Exalbuminous.*

Lythrum.

Sub-Class I.—Polypetalæ—*continued.*

Section C.—*Epigynæ.*

Cucurbitaceæ.

Corolla commonly *gamopetalous*; petals borne on the cup of the calyx. Flowers *declinous or polygamous.* St. 5, *in* 2 *coherent pairs*, *or* 1 with large *sinuous anther.* Ovary *unilocular or spuriously multilocular.*

Fruit.—Berry.

Seeds.—*Exalbuminous.*

Cucurbita.

Cacteæ.

St. *fleshy, and of the most various forms.* Leaves usually *tufts of spines.* Acyclic flowers, with *numerous sepals, petals, and stamens, which gradually pass into each other.* Ovary *unilocular, with horizontal ovules.*

Fruit.—Berry.

Myrtaceæ.

Leaves usually *opposite and dotted, with oil-glands.* St. *indefinite. None* of this order *are blue-flowered.* Placentation *axile.*

Fruit.—Berry, Drupe, Capsule, or Pome-like.

Seeds.—*Exalbuminous.*

Myrtus.

Umbelliferæ.

Inflorescence *umbellate* (usually compound). St. 5. Styles 2, *with fleshy base.* Bilocular ovary, *with* 1 *suspended ovule in each chamber.*

Fruit.—Schizocarp.

Umbelliferæ.

SUB-CLASS 2.—GAMOPETALÆ.

(All Gamopetalous Orders have Epipetalous Stamens, except Vaccinieæ, Ericaceæ, Campanulaceæ, and Lobeliaceæ.)

Section A.—*Hypogynæ.*

PRIMULACEÆ.

St. 5 *opposite to the petal lobes.* Placentation *free central.*

Fruit.—Capsule.

Note.—No corolla in *Glaux* (has petaloid calyx). Ovary half inferior in *Samolus.* Embryo has only 1 cotyledon in *Cyclamen.*

Primula.

GENTIANACEÆ.

Corolla lobes usually twisted in bud. Ovary composed of 2 *carpels*, with 1 or rarely 2 loculi, and *parietal* placentation.

Fruit. — Capsule or Berry.

Gentianeæ.

APOCYNACEÆ.

Corolla with *imbricate-contorted æstivation.* St. 5. Ovary composed of 2 *carpels*, usually connate only at their styles.

Fruit.—Bifollicular.

Seed.—Usually *Exalbuminous.*

Vinca.

BORAGINACEÆ.

Ovary 4 *lobed.* Style *gynobasic.*

Fruit. — Schizocarp, forming 4 Achenes.

Seeds.—*Exalbuminous.*

Boragineæ.

LABIATÆ.

Irregular flower. Ovary, Style, and Fruit as in Boraginaceæ.

Seed. — *Exalbuminous.*

Labiatæ.

SOLANACEÆ.

Ovary *bilocular* (nearly or quite 4 chambered in fruit of *Datura*), *with many campylotropous ovules.*

Fruit. — Capsule or Berry.

Solanum.

SUB-CLASS 2.—GAMOPETALÆ—*continued.*

Section A.—*Hypogynæ—continued.*

ASCLEPIADEÆ.

St. 5. The *ripe pollen form* masses or *pollinia* like that of Orchidaceæ.

Fruit.—Bifollicular.

Asclepias.

POLEMONIACEÆ.

St. 5. *Trilocular* ovary.

Fruit. — Loculicidal Capsule.

Polemonium.

CONVOLVULACEÆ.

Twining or trailing herbs. Corolla usually with *contorted or plaited æstivation.* St. 5.

Fruit. — Capsule or Berry.

Convolvulaceæ.

SCROPHULARIACEÆ.

Irregular flower. Ovary *bilocular, with many ovules.*

Fruit.—Capsule.

Scrophularineæ.

ACANTHACEÆ.

Flower *irregular.* St. *always* 4 *didynamous or* 2. Ovary *bilocular.* Ovules *few.*

Fruit.—Capsule.

Seed. — *Exalbuminous.*

Note.—It is absurd to separate this order from Scrophulariaceæ.

ERICACEÆ.

St. 8 *or* 10, *not epipetalous.* Anthers almost always *dehisce* by pores.

Fruit. — Capsule or Berry.

Erica.

SUB-CLASS 2.—GAMOPETALÆ—*continued.*

Section B.—*Epigynæ.*

VACCINIEÆ.

This order differs from Ericaceæ only in having an *inferior* ovary.

Vaccinium.

LOBELIACEÆ.

Like Campanulaceæ, but its flowers *are irregular*, and St. *syngenesious* (see Compositæ).

CAMPANULACEÆ.

St. 5 (often connate at base), *not epipetalous.* Ovary 2–5 *chambered, with indefinite ovules.*
Fruit.—Capsule.

Campanula.

CAPRIFOLIACEÆ.

Leaves *opposite.* Ovary 2–5 *locular.* Ovules *suspended.*
Fruit.—Berry.

Caprifoliaceæ.

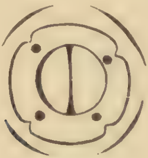
SUB-CLASS 2.—GAMOPETALÆ—*continued.*

Section B.—*Epigynæ—continued.*

RUBIACEÆ.

European species have an *angular* stem, *whorled* leaves (or rather opposite leaves, each with a pair of lateral leaf-like *stipules*), and *small* flowers. The exotics have scaly stipules. Corolla *valvate.* Ovary 1–2 *locular.*

Fruit. — Achene, Capsule, or Berry.



Asperula.

DIPSACEÆ.

Opposite leaves. Inflorescence *a capitulum.* Each floret has a little *involucel* (epicalyx). St. 4.

Fruit.—Achene.

Dipsacus.

COMPOSITÆ.

Inflorescence *a capitulum.* St. *syngenesious.*

Fruit.—Achene.

Seeds.—*Exalbuminous.*

Compositæ.

VALERIANACEÆ.

Opposite leaves. Flowers *irregular and small.* St. *fewer than petals.* Ovary *trilocular,* but not more than 1 loculus with 1 ovule develops to maturity.

Fruit.—Achene.

Seed.—*Exalbuminous.*

Valeriana.

Sub-Class 3.—Monochlamydeæ (Incompletæ).

Section A.—*Hypogynæ.*

Urticaceæ.

Stipulate herbs usually, *with stinging hairs.* Flowers *unisexual.* Ovary 1 *chambered, with orthotropous ovule.*

Fruit.—Achene.

Urtica.

Ulmaceæ.

Trees. Leaves *simple, with deciduous stipules.* Flowers almost always *hermaphrodite.* Inflorescence *a glomerule.*

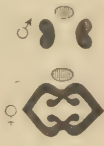
Fruit.—*Samara*, or small Drupe.

Ulmus.

Salicineæ.

Diœcious trees or shrubs, with both kinds of flowers *in spikes.* Flowers, *practically naked, are borne in the axils of bracts.*

Fruit.—Capsule.



Salix.

Euphorbiaceæ.

Flowers *unisexual.* Ovary *bi- or trilocular.* Commonly 1 pistillate and several staminate flowers are gathered within a small involucre, bordered by fleshy pieces, the whole forming a *Cyathium.* (No Cyathium in Dog's Mercury.)

Fruit.—Schizocarp.

Cyathium of Euphorbia.

Thymelæaceæ.

Shrubs. Flowers *hermaphrodite.* Perianth (calyx) *petaloid and* 4-*lobed.* St. 4 *or* 8, *adnate to perianth.* Ovary *unilocular, with* 1 *pendulous ovule.*

Fruit.—Berry.

Daphne.

SUB-CLASS 3.—MONOCHLAMYDEÆ (INCOMPLETÆ)—(*continued*).

Section A.—*Hypogynæ*—(*continued*).

CHENOPODIACEÆ.

Small flowers clustered to form a dense inflorescence. St. *opposite to the sepaloid perianth.* Ovary *unilocular, with* 1 *basal ovule.*

Fruit.—Achene.

Chenopodium.

POLYGONACEÆ.

Leaves *with ochreate* (perfoliate) *stipules.* Perianth *sepaloid or petaloid.* Ovary *like that of preceding order, but is* 3-*cornered.*

Fruit.—Triangular Achene.

Polygonum.

Section B.—*Epigynæ.*

CUPULIFERÆ.

Flowers *monœcious*, with perianth of 5 or 6 segments. Ovary *trilocular*, with 2 ovules in each loculus.

Fruit.—Nut (one-seeded) *invested by a hard capsule*, formed of connate bracteoles.

Quercus.

LORANTHACEÆ.

Diœcious or hermaphrodite. Parasites *provided with chlorophyll.* Ovary *unilocular*, with 1 erect ovule without an integument adhering to its wall.

Fruit.—Berry.

CLASS II.—MONOCOTYLEDONES.

SUB-CLASS I.—PETALOIDEÆ.

Section A.—*Hypogynæ.*

ALISMACEÆ.

Marsh or water plants. *Hermaphrodite or monœcious.* Outer perianth whorl *sepaloid.* Gn. *apocarpous* (carpels sometimes partially coherent), with 1–3 ovules in each ovary or distinct loculus.

Fruit.—Achene.

Seeds.—*Exalbuminous.*

LILIACEÆ.

Hermaphrodite (Ruscus is *diœcious*). Both perianth whorls *petaloid and regular.* St. 6, *rarely* 2 *or* 4. Ovary (usually *trilocular*) with *axile* placentation.

Fruit. — Capsule or Berry.

JUNCACEÆ.

Plants of grass-like aspect, with linear or tubular leaves. Perianth *dry, glumaceous, and brownish.* St. 6. Inflorescence *Anthela* (compound Cymose variety, in which the branches of the first order are gradually shorter from without inwards).

Fruit.—Capsule.

Alisma.

Lilium.

Juncus.

Sub-Class I—Petaloideæ—(*continued*).

Section B.—*Epigynæ*.

Scitamineæ.

Leaves *large, with pinnate venation.* Flowers *irregular.* Fertile St. 1 (in Musa 5). Ovary *trilocular.*

Fruit.—Capsule or Berry.

Seed.—*Has abundant perisperm*, and usually no endosperm.

Hedychium.

Iridaceæ.

St. 3. Ovary *trilocular.*

Fruit.—Capsule.

Iris.

Orchidaceæ.

Flowers *irregular.* Fertile St. 1 *or* 2, *gynandrous.* Pollen usually set free in 2 masses (*pollinia*). Ovary *unilocular*, with 3 *parietal placentas.*

Fruit.—Capsule.

Seeds.—*Exalbuminous.*

Orchis.

Amaryllidaceæ.

St. 6 (usually), *or* 12 *to* 18. Ovary *like that of Iridaceæ.*

Fruit.—Capsule or Berry.

Amaryllidaceæ.

SUB-CLASS 2.—NUDIFLORÆ.

(Perianth wanting, or consisting of Scales.)

AROIDEÆ.

Flowers *monœcious or hermaphrodite, and sessile in* inflorescence *on a spadix* (fleshy axis). Perianth 0 *or* 4–6, *polyphyllous, scale-like.*

Fruit.—Berry.

Acorus.

GRAMINEÆ.

Hermaphrodite. Flowers *small,* in *spikelets* of 2 or more, which have 2 *bracts or glumes* at their base. Outer perianth 0, inner are 2 *lodicules.* Each flower is protected by 2 "flowering" *glumes* (paleæ). St. usually 3, with *versatile anthers.* Stigmas 2, *feathery.*

Fruit.—Caryopsis.

Gramineæ.

PALMÆ.

Leaves *large.* Flowers *almost always diœcious or monœcious, small, and with double* perianth *on a branched spadix.* St. 6 (*rarely numerous*). Gn. 3.

Fruit.—Nut or Berry.

Palm.

CYPERACEÆ.

Grass-like, but the leaves *are arranged in* 3 *rows on the stem* instead of 2 rows, and their sheaths are always entire. Perianth 0, *or of* 3–6 *or more bristles or scales.* St. 3. Stigmas 3 *or* 2.

Fruit.—Achene (not Caryopsis).

Scirpus.

GLOSSARY.

Abjoint, to detach by septa.
Abjunction, detachment by septa.
Abnormal, contrary to the usual structure or function.
Abortive, **Abortion**, imperfect formation or non-formation.
Abscission, detachment by solution or disorganisation of the connecting zone.
Abstriction, used commonly as a substitute either for *abjunction* or *abscission*.
Achene, a one seeded, dry, indehiscent fruit.
Achlamydeous, without floral envelopes (calyx and corolla).
Acicular, needle-shaped, as the leaves of Pines.
Acrocarpous, a term used in the description of Mosses, and applied to individuals which develop archegonia on the summit of the primary stem, the growth of which is thereby arrested. *Funaria* is an acrocarpous moss. Compare with *pleurocarpous*.
Acrogenous, increasing by growth at the apex, or produced at the apex.
Acropetal, in the direction of the summit. Compare with *basipetal*.
Actinomorphous, same as *regular*. Compare with *zygomorphous* or *irregular*.
Acuminate, taper-pointed, applied to the apex of the leaf.
Adelphous, applied with a prefix to stamens united by their filaments (stalks). See *monadelphous*, *diadelphous*, *polydelphous*.
Adhesion, union of dissimilar parts. Compare with *cohesion*.
Adnate, **Adherent**, same as adhesion. The anther of the stamen is said to be adnate when fixed by its whole length to the filament or its prolongation.
Adventitious, produced out of normal or acropetal order. Branches borne on dissimilar members (as roots on stems or leaves) are also considered to be adventitious.
Æcidiospores, spores formed in an æcidium.
Æcidium. In Uredineæ Fungi, a cup-shaped sporocarp, having a hymenium at the inner bottom of the structure, from the basidia of which spores (that fill the cup and drop out through the ruptured apical part of the *peridium* or envelope) are successively and regularly abjointed.
Æstivation, the mutual arrangement or grouping of floral leaves in the bud. Compare with *vernation* and *ptyxis*.

Aggregate fruit, collection of apocarpous fruits, the product of one or more neighbouring flowers.

Albumen, a tissue of reserve food stuffs occurring outside the embryo in seeds, and formed after the fertilisation of the ovum.

Albuminoids, proteids.

Albuminous seeds, furnished with albumen tissue.

Alburnum, the outer young, or sap wood of a tree.

Alternate, not opposite.

Alternation of generations, the alternation of the *Oophyte* or sexual organ bearing stage or segment, with the *Sporophyte* or spore bearing stage or segment in the life history of plants.

Amentum, same as *catkin*.

Ameristic prothallia. In Filices, prothallia too poorly nourished to be capable of producing archegonia; they may, however, bear numerous antheridia.

Amphithecium, the peripheral layer of cells surrounding the *endothecium* (*q.v.*) in the differentiation of the capsule of Moss.

Amplexicaul leaves, sessile or shortly stalked leaves which clasp the stem by the lobed bases of their blade.

Amylogenesis, formation of starch and other carbohydrates.

Amylum-bodies. In Desmidieæ and other Algæ, having chloroplasts in the form of bands, plates, or stars, also in higher plants. They occur in these chloroplasts as minute round or lenticular bodies, and their function is the manufacture of starch, doubtless by dehydration from the glucose previously elaborated by the body of the chloroplastid. Same as *pyrenoids*.

Analogous, having the same function.

Anastomose, to form a network. Same as *reticulate*.

Anatropous or inverted, applied to the ovule when the micropyle is turned to the placenta and the funiculus or stalk is attached to the outer coat of the ovule, forming a projection known as the *raphe*.—*See* Fig. 48, page 69.

Andrœcium, a collective name for all the stamens or male sporophylls of a single flower.

Androspore. In Œdogonieæ (Algæ) a zoosperm or swarm spore which gives rise to a minute short-lived *dwarf-male* that adheres to the oogonium and naturally develops two spermatozoids.

Anemophilous plants. Phanerogams which are pollinated by the agency of wind. Compare with *hydrophilous*, *zoidiophilous*.

Angiocarpous. In higher Fungi, applied to forms in which the hymenial layer is disposed inside the tissue of the sporocarp. Opposite to *gymnocarpous* (*q.v.*)

Angiospermæ, a section of Phanerogams or spermaphyta having their ovules inclosed in an ovary and fertilised through the medium of a stigma.

Anisostemonous, applied to an andrœcium when the number of its stamens is not equal to that of the parts of the corolla and of the calyx (or to the latter only in single perianthed flowers). Compare with *isostemonous*.

Annual, a plant which produces seed and dies in the first year of its existence.

Annulus. In Filices, the row of special cells in the wall of the sporangium, by the contraction of which, on drying at maturity, the rupture of the capsule is brought about. In Musci, is a ring of peridermal cells which, by the swelling of their walls and subsequent detachment, effect the removal of the operculum of the capsule.

Anterior portion, of a flower or branch structure, the side turned away from the parent axis is anterior. Thus, in a pea blossom, the keel is anterior and the standard posterior.

Antero-posterior plane, a vertical plane bisecting the anterior and posterior sides of a flower or other lateral structure.

Anthela, a compound cymose inflorescence in which the branches of the first order are gradually shorter from below upwards (or from without inwards). The Anthela is, in fact, just a kind of irregular cymose corymb.

Anther, the part of the stamen which develops the pollen-grains or microspores, *i.e.*, the united microsporangia or pollen-sacs structure borne upon the male sporophyll or staminal leaf of Phanerogams.

Antheridium. In Cryptogamæ, a male sexual organ producing in its interior spermatozoids (usual) or spermatia.

Anticlinal walls are those which form towards or cut at right angles the periphery of a part. Compare with *periclinal.*

Antipodal cells, three rudimentary cells formed at the base of the embryo-sac (macrospore) in Angiospermæ, before fertilisation, by the division of the primary nucleus.

Apetalous, without petals.

Apocarpous, having separate carpels. Compare with *syncarpous.*

Apogamy, loss of sexual function. The sexual organs may be present but are functionless, although a new plant may be produced from the female organ. Apogamous plants usually exhibit parthenogenesis (*q.v.*) Compare with *apospory.*

Apophysis, the enlargement of the seta at the base of the capsule in certain genera of Musci.

Apospory, loss of the power of producing spores. The sporogenous organs may be present but are functionless as far as the production of spores are concerned, although a new plant may be developed directly from them or in their vicinity.

Apothecium, the name applied to the ascocarp in some Ascomycetes, in which the hymenium is exposed while the asci are developing. Same as *discocarp.*

Archegoniatæ, a division of plants having their female organs in the form of archegonia.

Archegonium, a female sexual organ, consisting of a neck portion and a roundish expanded basal part or venter. The whole may be entirely or partially above the surrounding tissue, or wholly or partly within it. The neck is pierced by a canal (with usually one or more neck canal cells) leading down to the interior of the venter which contains the ovum, and a smaller cell, the ventral canal cell, above it.—*See* Fig. 109.

Archesporium. In Archegoniatæ and Angiospermæ, the cell or group of cells from which the mother cells of the spores are formed.

Archicarp, a unicellular or multicellular female organ devoid of any special receptive and transmitting apparatus, and in which the protoplasm of the interior or of the central cell is not rounded off to form a typical ovum.

Aril, **Arillode**, any outgrowth of the stalk, placenta, or integument of a seed.

Ascocarp. The general name applied to the sporocarps of Ascomycetes which produce asci and ascospores. There are three varieties:—*apothecium* or discocarp, *perithecium* or pyrenocarp and *cleistocarp* (*q.v.*)

Ascogonium, same as *archicarp*.

Ascospore, a spore produced in an ascus.

Ascus (*pl.* Asci), a club-shaped or globular cell in an ascocarp, within which spores (normally eight) are developed.

Asymmetrical flower, contrary to *symmetrical* (*q.v.*)

Aulophyte, the name given to a plant which lives in the interior of another, but not as a parasite.

Auriculate, furnished with ear-like appendages.

Autœcious, applied to parasitic Fungi which pass through all the stages of their full development on the same host. Compare with *heterœcious*.

Autoxeny, pertaining to the autœcious condition.

Auxospore. In Diatomaceæ, a relatively very large cell, produced either by growth alone, or as the result of conjugation and subsequent growth, which is the starting point of a series of successive free bi-partitions, the resulting daughter cells being successively smaller, until a minimum is reached, when an Auxospore is again developed.

Axil, the acute angle formed on the upper side by the attachment of a lateral member.

Axillary, in or belonging to the axil. Compare *extra-axillary*.

Baccate, berry-like.

Basal wall, the first wall which forms in the fertilised ovum of Archegoniatæ, dividing that body into an anterior and a posterior half.

Basidia, mother cells from which spores are cut off by abstriction at the free extremity.

Basidiospore, a spore cut off by abjunction from a basidium.

Basilar or basal style, a style which apparently rises from the base of a simple ovary. See *gynobasic style*.

Basipetal, towards the base. Applied to a form of branching in which the youngest members are nearest the base. Compare with *acropetal*.

Berry, a succulent indehiscent fruit, the *pericarp* (*q.v.*) of which consists of a more or less tough epicarp or skin, and a succulent pulp which fills the interior, and in which the seeds are imbedded.

Biennial, living two years. Springing from the seed the first year and flowering and dying the next.

Bilabiate, two lipped.

Bilocular ovary, having two loculi or seed chambers.

Biparous cyme, same as *dichasium*.

Bisexual, with both male and female organs. A bisexual flower is the same as *hermaphrodite.*

Bostryx, same as *helicoid cyme.*

Bract, any leaf near a flower, or a leaf from the axil of which a flower springs.

Bracteole, a small bract seated *upon* the pedicel or flower stalk, or at the base of this, or of the flower in a compound inflorescence.

Bract scale (cone scale), the scale of the cone in Coniferæ above which lies the *seminiferous scale* (carpel).

Branch, the lateral development of a similar part.

Brood cell, same as *gonidium.*

Brood gemma, same as *gemma.*

Bud, a unicellular or pluricellular *branch* in the earliest stage of its development.

Bulb, a fleshy bud which has departed from its normal function and become a storehouse of nutriment. It is biennial, and, in growing the second year, shoots forth a flowering stem from the centre, and gives off roots from the base.

Bulbil, a *deciduous* leaf bud capable of propagating its kind.

Bundle-sheath. In young roots, a limiting cell layer (or layers) which forms a common external cylindrical sheath to both the xylem and phlœm elements of the central vascular tissue. In certain young stems of Dicotyledons and Gymnospermæ it can also be traced as a ring outside all the bundles, but in other vascular families it almost invariably occurs as a more or less complete sheath to a single vascular bundle. Same as *plerome sheath* or *endodermis.*

Caducous, falling off early. Applied to sepals or petals which drop off at or before the time of expansion of the flower.

Calceolate, slipper-shaped.

Callosity, a coriaceous thickening or consistence on a limited portion of an organ.

Callus, the thickening material on and around sieve-plates.

Calycifloræ, polypetalous Angiosperms having their stamens adherent to the calyx.

Calycine, belonging to, or of the nature of a calyx, or resembling a typical calyx.

Calyculus, same as *epicalyx.*

Calyptra, the enlarged venter of the archegonium in Muscineæ which, after the development within it of the sporocarp, has been ruptured. The upper part of the Calyptra is frequently carried up like a cap on the summit of the *capsule* as the seta or stalk of the latter elongates.

Calyx, the outer envelope whorl of a double perianthed flower. A single perianthed flower is reckoned to have only a calyx covering. See *perianth.*

Cambiform tissue, the living elongated parenchymatous tissue on either side of the cambium-layer not yet metamorphosed into the elements of wood or bast.

Cambium, the meristem layer from which the *secondary* wood, bast, and medullary rays of Dicotyledons and Gymnosperms, are formed.

Campanulate, bell-shaped.

Campylotropous ovule, an ovule the *body* of which is *bent on itself*, so that the micropyle is brought near to the point of attachment of the funiculus. Compare with *orthotropous* and *anatropous*.

Canaliculate, channelled.

Cancellated, latticed.

Cap cells. In nucellus of Angiosperms, the three upper sister cells of the embryo sac which are squeezed together by the development of the latter, and appear for a time as a cap on its summit before they are utterly disorganised.

Capillary, hair-like.

Capillitium. In Myxomycetes, hardened sterile protoplasmic threads or filaments generally combined into a network occurring within the spore capsule, and functioning as looseners of the spore masses at the time of scattering of the spores.

Capitulum. In Angiosperms, an indefinite form of inflorescence with *sessile* flowers in which the axis is so greatly contracted that the flowers are all brought close together into a common head.

Capsule. In Muscineæ, the upper portion of the sporocarp in which the sporangium is formed. In Angiosperms, a dry dehiscent fruit (not a siliqua or silicula) composed of more than one carpel.

Carinal canal, the internodal longitudinal air passage contained by, or lying on the inner side of, each vascular bundle of Equisetum. Each carinal canal lies opposite a ridge on the stem surface.

Carpel, female sporophyll of Phanerogams. If it stands free it naturally constitutes a pistil by itself, but it is usually united with one or more other carpels to form a *syncarpous* pistil.

Carpellary, of the nature of, or belonging to, a carpel.

Carpogeneous cells, the cells of a carpogonium which after fertilisation grow out to form a sporocarp.

Carpogonium, the lower and bulky portion of a *procarp* (*q.v.*) which consists of carpogeneous cells (*q.v.*) alone, or of these along with sterile cells. The *archicarp* is a form of carpogonium devoid of any special receptive and transmitting apparatus.

Caruncle, a kind of aril; a localised outgrowth of the testa or outer coat of a seed usually at or near its apex. *Examples*.—Seeds of Polygala, Viola, Chelidonium.

Caryopsis, a form of achene in which the pericarp or ripe ovary wall is adherent to the coat of the seed. The latter therefore entirely fills the cavity of the ripe ovary. The grain of wheat is a good example.

Cataphyll, scale leaf.

Catkin, deciduous spike. Same as *Amentum*.

Caulicle, a tiny embryonal stem, or a little rudimentary stem.

Cauline vascular bundle, a bundle always remaining in the stem.

Centimetre (Metric System Measure), the hundredth part of a metre; the tenth part of the decimetre; ten times the length of the millimetre, and equal to 0·39 of an English inch.

Central cell of archegonium, cell in the interior of the venter from which the ovum and the much smaller ventral canal-cell are formed, first by bipartition and then by a kind of rejuvenescence and rounding off.

Centrifugal, produced or expanding in succession from the centre or apex outwards towards the circumference, or downwards towards the base. When applied to an inflorescence, the same as *definite* (*q.v.*)

Centripetal, opposite of centrifugal. When applied to an inflorescence, the same as *indefinite* (*q.v.*)

Chaff scale, same as *palea* and *ramentum.*

Chalaza, the base of the nucellus or body of the ovule where the coats and nucellus blend together.

Characters, distinguishing differences.

Chlorotic leaves, foliage leaves which are pale or white, owing to the want of the necessary iron for the formation of chlorophyll.

Choripetalous, same as *polypetalous.*

Choriphyllous, same as *polyphyllous.*

Chorisepalous, same as *polysepalous.*

Chorisis, development of two or more members (as stamens) where only one should be. Same as *dédoublement*, *duplication*, *doubling.*

Cicatrix, scar left by the falling off of a leaf or other organ.

Cicinus, same as scorpioid cyme.

Cilia, vibratile thread-like protoplasmic processes, straight and undulating or coiled, by the living action of which zoogametes, zoogonidia, or zoospores, move. In Musci the teeth of the peristome are also, unfortunately, known as cilia.

Circinate ptyxis, rolled up inwards from the apex towards the base.

Circulation of protoplasm, the streaming of living protoplasm from and towards the neighbourhood of the nucleus. Compare with *Rotation.*

Circumscissile, applied to the dehiscence of certain capsular fruits, and signifies the splitting by a circular line round the sides, not longitudinal, but transverse. *Example*—Pods of Plantain, &c.

Cirrhose, furnished with a tendril, or resembling or coiling-like tendrils.

Cladode, same as *Cladophyll.*

Cladophyll, a branch stem of one internode, which simulates a typical leaf.

Claw of petal, the narrow or stalk-like base of some petals.

Cleistocarp. In Ascomycetes, an *Ascocarp* (*q. v.*), with a completely closed envelope of cells, within which the asci and ascospores are maturely developed, and from which they are liberated by the ultimate decay or rupture of the aforesaid covering. *See* also *perithecium.*

Cleistogamous flower, an unexpanding hermaphrodite flower that fertilises itself.

Climbing plants, weak plants which ascend by bodily twining round supports, or by clinging to objects by means of tendrils, or by metamorphosed roots, &c.

Closed vascular bundles, bundles without cambium.

Coalescence, the blending or running into one of two or more bodies.

Cœnobium, a colony of organically independent organisms gathered within a common investment or secretion.

Cohesion, union of similar parts. Compare with *adhesion.*

Coleorhiza. In Monocotyledonous seed, the tissue sheath (root-sheath) outside and enclosing the radicle of the embryo, but continuous with the root-cap of its tip.

Collateral vascular bundle, a vascular bundle in which the xylem and phlœm are placed side by side. Compare with *concentric*.

Collective fruit, a mass or aggregate of fruits resulting from several or many neighbouring flowers. *Examples*—Pine Apple, Mulberry, Fig.

Collenchyma, the name applied to the hypodermal cells of the cortex when they are thickened at the mutual corners.

Columella. In Muscineæ, the body of barren tissue in the centre of the capsule, around which the sporangium is developed.

Common vascular bundle, a bundle which belongs in one part of its course to a leaf, and in another to the stem. See *leaf-trace*, and compare with *cauline bundle*.

Complete flower, one which has calyx, corolla, stamens, and pistil.

Compound leaf, a leaf the blade of which is divided into leaflets by separations extending right into the mid-rib.

Compressed, flattened laterally. Compare *depressed*.

Concentric vascular bundle, a bundle in which the xylem tissue is surrounded by the phlœm. Compare with *collateral*.

Conceptacles. In Fucaceæ and Rhodophyceæ, the special cavities on the surface of the thallus, in which the sexual organs or spores are produced.

Conduplicate, folded upon itself lengthwise, as the standard or largest petal of the Pea Blossom, the young leaves of the Cherry, &c.

Conidium, same as *gonidium*.

Conjugation, the coalescent union of two similar gametes (one male and one female).

Conjunctive tissue, filling up tissue; applied to the parenchymatous tissue between (and on the inner side of) the wood and bast groups in the vascular cylinder of young roots.

Connate leaves, opposite sessile leaves, the lobes of which are united to each other around the stem.

Connective, the uppermost part, or rather perhaps the continuation of, the central portion of the filament of a stamen which unites the two lobes of its anther.

Contorted, twisted.

Convolute ptyxis, rolled up by the upper surface from side to side.

Cordate, heart-shaped.

Coriaceous, leathery, or tough, and continuously compact.

Cormophytes, all plants other than Thallophytes with stems and leaves.

Corolifloræ, a section of Dicotyledons, having *gamopetalous* flowers, and, with rare exceptions, *epipetalous* stamens.

Corolla, the inner of the two envelope whorls of a double perianthed flower. See *perianth*.

Corolline, like, or of the nature of, or belonging to, a corolla.

Corona, a whorl of corolline or perianth ligules whether united or free. A good example of petals with *free* ligules is found in *Symphytum* (Boraginaceæ), and of a similar double perianth with *united* ligules in *Narcissus*.

Corpusculum, an archegonium of Coniferæ. According to Balfour, however, only the central cell of the archegonium of that order.

Cortical, pertaining to the cortex.

Cortina. In Hymenomycetes, the remains of the *velum partiale*, which continues adherent to the rim of the pileus.

Corymb, a *raceme* in which the lower flower stalks are so much longer than the upper and inner ones, that the whole flowers of the inflorescence are held up together, so as to constitute a roughly-flat or low-arched summit. *Examples*—Wall-flower, Hawthorn.

Cotyledon, first leaf of embryo.

Cremocarps, the achenes resulting from the natural splitting of the schizocarpous fruit of Umbelliferæ.

Crenate leaf, margined with broad rounded teeth.

Crest on seeds, same as *Caruncle.*

Cross-fertilisation, impregnation of the ovum of one flower by the male gamete of another.

Cross-pollination, the dusting of the stigma (or in Gymnosperms of the micropyles of the ovules direct) of one flower with the pollen from another.

Cruciform, cross-shaped, or arranged in the form of a cross.

Cryptogamæ, the name under which the very varied plants of the vegetable world that do not produce seeds are grouped.

Cryptogamic or Cryptogamous, pertaining to the Cryptogamæ.

Crystalloid, a crystal of organic substance. In Botany applied exclusively to crystals of albuminoid matter.

Culm, a hollow (but solid-noded) stem which bears leaves at each node or joint, the latter giving it a knotty appearance on the exterior.

Cupule, a hard involucre in the form of a more or less complete cup, developed, after fertilisation, below a flower or an inflorescence.

Cuspidate, tipped with a sharp stiff point.

Cut, applied generally to any indentation or deep division.

Cuticle, the external corky portion of epidermal walls.

Cuticularisation or suberification, transformation of cell-walls *into*, or impregnation *with*, cork, or the deposition of the latter material *on* existing walls.

Cyathium, the inflorescence of *Euphorbia*, consisting of a tubular involucre, with alternating glandular appendages of a crescentic form, within which is one female flower surrounded by five groups of male flowers, each consisting of a single stamen (*see* page 209).

Cyclic flower, a flower the leaves of which are arranged in whorls.

Cyme, a form of monopodial branching in which the apical growth of the parent axis entirely ceases, and the lateral shoots grow up above it.

Cymose, of the nature of a cyme.

Cymose umbel, an umbel the peduncles of which arise in a whorl a little distance below the apex of a parent axis whose upward growth has ceased.

Cypsela, the solitary achene resulting from the ripening of the inferior ovary of Compositæ, Dipsaceæ, Valerianiaceæ. (This term should be abolished.)

Cystocarp, same as sporocarp.

Deciduous, falling off in the same season or year in which formed.

Decurrent, running down, in, or on to another structure. Applied to leaves prolonged on the stem beneath their insertion, as in Thistles.

Decussate leaves, opposite leaves, the contiguous pairs of which stand on the stem at right angles with regard to each other.

Deferred shoots, shoots ultimately produced from buds which have remained dormant throughout one or more seasons.

Definite, in inflorescence, same as *cymose*. Roughly, a flower cluster in which the oldest flower is at the apex of the oldest axis or in the centre of stamens; not more than twelve in a flower (Balfour says not more than twenty). Compare *indefinite*.

Dehiscence, the manner in which the wall of a mature organ ruptures or opens to allow the contents to escape.

Dehiscent, rupturing or opening at one or more parts to allow the contents to escape. Compare *indehiscent*.

Dentate, toothed.

Depressed, flattened vertically. Compare *compressed*.

Dermatogen. Balfour defines this as "the primordial meristematic epidermis of a growing point."

Diadelphous, in two bundles, applied to stamens united by their *filaments*. Compare *syngenesious*.

Dialypetalous and Dialysepalous. Same as *polypetalous* and *polysepalous* respectively.

Diaphragm. In Heterosporous Pterodophyta, the layer separating the prothallus from the cavity of the macrospore. In Equisetum, the transverse continuous plate of tissue in the nodes of the stem. In Chara, constriction in the neck of nucule or female sexual organ.

Dichasium, a cyme (*q. v.*) in which the lateral axes are developed in opposite pairs. Same as *biparous cyme* and *false dichotomy*.

Dichlamydeous flower, having both calyx and corolla or double perianth.

Dichogamy, maturity of the andrœcium and gynœcium of a hermaphrodite flower at different times.

Dichotomy, forking at the apex by gradual separation of the growing point and subsequent divergent growth of the parts.

Diclinous, unisexual. Applied to flowers having the stamens in one flower and the gynœcium in another. Compare *hermaphrodite*.

Didynamous, having four stamens in two pairs, one of which is shorter than the other.

Differentiated, specialised in structure and function.

Digitate leaf, a compound or nearly compound palmate leaf, in which the leaflets or lobes are spread out somewhat like the stretched fingers of a hand.

Dimorphous, of two forms. Applied to flowers of the same species with different lengths of stamens and pistil, the one with the higher placed anthers having the shorter style or lower placed stigma, and *vice versâ*. Same as *heterogony*. Compare *trimorphism*.

Diœcious, having the male and female organs of the same species on different individuals. Compare *monœcious*.

Diplostemonous andrœcium, applied when the stamens are in two normally alternating whorls. Compare *obdiplostemonous*.

Discocarp, same as *apothecium.*
Disc or Disk, generally understood now-a-days as a more or less fleshy outgrowth of the floral receptacle between the stamens and gynœcium.
Dissected, deeply cut.
Dissepiment, partition.
Distichous, placed in two ranks or rows in front and behind, or above and below each other.
Dorsal suture. In Ovary, the midrib, or line of place corresponding to the midrib of a carpellary leaf. Compare *ventral suture.*
Dorsiventral, with distinct dorsal and ventral surfaces. Compare *radial.*
Double flower, one in which the petals are unduly or monstrously multiplied, as in the Garden Rose.
Drupe, a succulent indehiscent fruit, the pericarp (*q. v.*) of which consists of a skin (epicarp), a middle fleshy portion (mesocarp), and an inner indurated part or stone (endocarp), within which is the seed.
Duramen, the heart wood of a Dicotyledonous or Gymnospermous tree. Compare *alburnum.*
Dwarf-male. In Œdogonium, a very simple few-celled plant body of short existence, which develops near the oogonium and produces spermatozoids.

Ebracteate, without bracts.
Egg apparatus. In Angiospermæ, the ovum and two synergidæ at the micropyle end of embryo-sac of ovule. The group is in fact a rudiment of the typical archegonium of lower plants.
Elaters. In Equisetum, four hygroscopic membranous bands formed by the tearing of the outermost (and third) coat of the spore, to which at one part they remain attached; their special function being to keep the spores together in small groups as they leave the sporangia. In Hepaticæ, long dead fusiform cells with spiral wall thickenings, which loosen the spore masses at the time of their escape from the capsule.
Embryo, a plant in the earliest stages of its development, while it is yet dependent for nutrition on the parent or on the living storing cells of a surrounding tissue formed by and detachable from the parent, or on food previously stored up in a portion of its own body by the parent.
Embryo-sac, the macrospore of Phanerogams permanently contained within the ovule (macrosporangium).
Endocarp, the indurated inner portion of the pericarp of the drupe (*q. v.*).
Endodermis, bundle sheath. In young roots is present as a cylinder of cells outside the pericambium. Also occurs generally as a strengthening layer (or layers) round the closed vascular bundles of stems and leaves.
Endogenous, arising inside another body.
Endogonidium, a gonidium originating within a receptacle (gonidangium).

Endophyte, a plant which grows inside another.

Endosperm. In Angiospermæ, the storing tissue formed within the embryo-sac after fertilisation, and serving for the nutrition of the embryo (*q. v.*) Here it is synonymous with the *albumen* of a seed. In Gymnospermæ, the so-called primary endosperm is a prothallus, the secondary endosperm is the primary, further developed and converted into a food reserve tissue for the use of the embryos. In Selaginella, the tissue formed below the prothallus in the macrospore.

Endosporium, the innermost coat (cellulose) of a spore. See *Intine.*

Endothecium. In Musci, the central cells in the earliest stages of the differentiation of the capsule. In Phanerogams, the tissue of the wall of the mature anther within the epidermis (exothecium).

Entomophilous, pollinated by the carrying agency of insects.

Epibasal portion, the anterior half of a proembryo (*q. v.*).

Epicalyx, a whorl of calycine stipules.

Epicarp, the skin or outermost layer of the pericarp of a fruit.

Epidermis, the outermost layer of cells of at least young plants, forming a continuous skin with cuticularised outer surface.

Epigynous flower, having the other parts of the flower inserted on the top of the ovary. Compare *hypogynous.*

Epinasty, the opposite of *hyponasty* (*q. v.*).

Epipetalous, inserted on or adherent to the petals.

Epiphyte, a non-parasitic plant growing upon the outside of another.

Etiolated, blanched by excluding light, and so preventing the proper formation of chlorophyll.

Eucylic flower, same as *isomerous* (*q. v.*), but always with the parts of consecutive whorls alternating.

Eusporangiate, having sporangia formed from a group of cells. Compare *leptosporangiate.*

Exalbuminous seed, a seed without endosperm (*q. v.*).

Excipulum. In Lichens, the rim or outer partial envelope which the thallus forms round the ripe sporocarp.

Exogenous, arising on the outside, or increasing by additions to, or growth on, the outside.

Exosporium, the second or outer coat (except in Equisetum, where there is a third) of a spore.

Exstipulate, without stipules.

Extine, the exosporium of a pollen grain (*q. v.*). Compare *intine.*

Extra-axillary, arising beyond or out of the axil of a leaf.

Extrorse, applied to anthers which have their loculi turned outwards, and therefore dehisce towards the outer whorls of the flower.

False axis, same as *sympodium.*

False dichotomy, same as *dichasium* and *biparous cyme.*

Fascicle, a cymose inflorescence, consisting of a number of flowers on pedicels (*q. v.*) of equal length, *e.g.*, Sweet William.

Fascicled or fasciculated, growing in a bundle or tuft, as the leaves of Larch and roots of Dahlia.

Fascicular cambium, the cambium of the primary vascular bundles of Dicotyledons and Gymnosperms. Compare *interfascicular.*

Fertilisation, the name applied to the sexual union when the male and female gametes (*q. v.*) are dissimilar.

Fertilisation-tube, pollinodium-tube. In Peronosporeæ, the tube put out by the antheridium (pollinodium), which penetrates the wall of the oogonium (*q. v.*), and is the channel through which the central protoplasm (*gonoplasm*) of the former is discharged into or against the ovum of the latter.

Filament, stalk of a stamen, also any elongated slender structure.

Filiform, long, slender, and cylindrical.

Floral diagram, diagrammatic plan of the flower.

Floral envelopes, the more leaf-like external whorl or whorls of the flower outside the essential organs (stamens and gynœcium).

Floral formula, the expression by means of signs, abbreviations, and figures, of the states of regularity and completeness of the flower, of the number of the parts and their freedom or cohesion and adhesion, and of the relative position of the gynœcium.

Foliaceous, leaf-like, or bearing leaves (foliose).

Foliage-leaves, the typical green manufacturing leaves of the higher plants.

Foliar gaps, the meshes in the vascular net-work cylinder of Fern stems, from the margins of which branch bundles pass out into the leaf.

Follicle, a dry, monocarpellary, pod-like fruit, dehiscing by the ventral suture only.

Foot, an embryonal organ of attachment and suction, developed from hypobasal part of pro-embryo.

Fovea, Foveola. In Isœtes, the former being the depression on the upper surface of the leaf-sheath in which the sporangium is formed, and the latter the little depression above that from out of which the ligule arises.

Free, not united with any other parts of a similar or different sort.

Frondose, same as *thalloid.* Do not confound with *frond*, which in every-day language answers to the foliage leaves of Ferns.

Fructification. In Phanerogams, the state of fruiting. In Cryptogams, any sporogenous structure, or collection of sporogenous structures.

Fruit. In Angiosperms, the mature ovary and its contents (seeds).

Fruticose. In Lichens, shrub-like.

Fundamental tissue, the tissue of the body of a plant, not belonging to the epidermis (or periderm) or to the vascular bundles.

Funiculus or Funicle, stalk of ovule.

Fusiform, spindle-shaped.

Gamete, a unicellular motile or non-motile, naked or walled, sexual protoplasmic body.

Gamopetalous flower, having united petals. Same as *monopetalous* and *sympetalous.* Compare *polypetalous.*

Gamophyllous flower, a flower of a single, or double similar, or nearly similar, perianth, with all the parts united in common. Compare *polyphyllous.*

Gamosepalous, having united sepals. Same as *monosepalous* and *synsepalous.* Compare *polysepalous.*

Gemma, a simple variety of the deciduous-pluricellular bud, without differentiation into stem and leaf.

Genetic spiral, the spiral line passing through the point of insertion of all the alternately-arranged leaves on an axis in order of age, from older to younger. Same as *generating* or *fundamental* spiral.

Genus, a kind; a rank above species.

Geotropism, the study of the phenomena of growth as affected by gravitation.

Germ-cell or germinal vesicle, ovum in embryo-sac of Angiosperms.

Germ-nucleus, a nucleus resulting from the sexual coalescence of a *male pronucleus* and *female pronucleus* (*q. v.*).

Germ-tube, the tube of the endosporium (*q. v.*) of a spore produced in germination.

Germination, the act of sprouting; the first extended growth of a body initiating the course of development into a more complex state. In seeds, we specially mean the process by which the embryo unfolds its parts.

Gibbous, more tumid at one part than another, as the two larger opposite sepals of Wall-flower.

Gland, secreting organ.

Glans, same as Nut.

Glomerule, a cymose inflorescence, consisting of a few sessile or shortly pedicillate flowers, as in the Nettle. The *verticillaster* of the Labiatæ is a variety of this.

Glumes, the bracts of Gramineæ.

Gonidangium, a receptacle within which gonidia are formed.

Gonidial layer. In Lichens, the stratum of algal cells in a *heteromerous* (*q. v.*) thallus.

Gonidium, a naked or walled propagative cell, originating asexually, and separating from the parent. Same as *brood cell.*

Gonophore, a stalk supporting both the male and female organs of a hermaphrodite flower. Compare *gynophore.*

Gonoplasm. In Peronosporeæ, the central portion of the protoplasm of the antheridium or pollinidium, which passes through the fertilisation-tube of the latter into the oogonium and coalesces with the ovum. Compare *periplasm.*

Gymnocarpous. Fungi having the hymenium exposed while the spores are forming are gymnocarpous. Compare *angiocarpous.*

Gymnospermous, bearing ovules not enclosed in an ovary.

Gymnostemium, the structure formed by the adhesion of the stamens of a flower to the gynœcium, as in Orchidaceæ.

Gynandrous stamens, stamens adherent to the gynœcium.

Gynobasic style, defined by Balfour as "a style (of a syncarpous gynœcium) adhering by its base to a prolongation upwards of the torus (*q. v.*) between the carpels."

Gynœcium. In Phanerogams, the whole series of carpels or female sporophylls in a single flower.

Gynophore, stalk supporting the female organ of a flower.

Habit, general aspect or mode of growth.

Habitat, the place in which the plant lives in a wild state.

Hastate, halberd shaped, *i.e.*, with a spreading lobe on each side at the base.
Haustoria, parasitic roots. Special organs of attachment and suction.
Head. In Angiosperms, same as *capitulum.*
Helicoid cyme, sympodial branching in which each successive axis is placed on the same side.
Hemicyclic flower, when the parts are arranged, some in whorls (perianth, usually), and the others (stamens, usually) in a spiral.
Herbaceous. A plant is said to be herbaceous when the stem has a complete epidermis and normal cortex or outer parenchymatous ground tissue. Compare *woody.*
Hermaphrodite flower, having both male and female organs.
Hesperidium, a multilocular berry with firm and more or less thick rind, as the orange.
Heterocysts. In Nostocaceæ, the single larger and clearer cells of the filament incapable of further development.
Heterœcism, change of hosts. Parasitic Fungi are said to be heterœcious when they pass through different stages of their development on different hosts. Same as *metoxeny.* Compare *autoxeny.*
Heterogony, a condition in which different individuals of the same species have different lengths of styles and stamens; in the one case the stigma is carried above the tops of the anthers, and in the other it is below their level. There are two varieties:—*dimorphism* (dimorphous) and *trimorphism* (*q. v.*) Same as *heterostyly.* Compare *homogany.*
Heteromerous. In Lichens, a thallus in which the algal cells ("gonidia") are arranged together in one layer, so that the interlacing hyphal tissue is divided into an upper and lower (or outer and inner) layer. Compare *homoiomerous.*
Heterophyllous, applied to a plant having foliage leaves of different forms, as in Shepherd's Purse.
Heterosporous, giving rise to two kinds of asexually produced spore, viz., microspores and macrospores.
Heterostyly, same as *heterogony.*
Hilum. In Seed, the scar left on the seed-coat by the breaking away at maturity of the body of the seed from its stalk or placenta.
Hirsute, Hispid, with stiff hairs.
Homogamy, maturity at the same time of the stamens and gynœcium of a hermaphrodite flower. Compare *dichogamy.*
Homogony opposite of *heterogony.* A condition in which the relative heights of the anthers and stigmas of hermaphrodite flowers of the same species remain practically constant. Same as *homostyly.*
Homoiomerous, opposite of *heteromerous* in Lichens. Applied when the algal ("gonidia") and hyphal constituents of the thallus are uniformly distributed.
Homologous, having the same position and development or structural relation.
Homosporous, having only one kind of asexually produced spore. Compare *heterosporous.*
Homostyly, same as *homogony.*

Hormogonia. In Nostocaceæ, the freed rows of roundish cells from which new colonies are formed.

Hybrid, a cross between two species.

Hydrophilous, pollinated by the agency of water. Compare *anemophilous*, *zoidiophilous*.

Hymenial gonidia. In Lichens, the algal cells in the sporocarp.

Hymenium. In Fungi, a layer of terminating portions of hyphæ which have become spore mother cells.

Hyphæ, the elongated branching cell filaments which together form the bodies of all except the lowest Fungi.

Hypobasal part, the posterior half of a pro-embryo. Compare *epibasal*.

Hypocotyl, Hypocotyledonary. The first is the name of that part of the stem of an embryo below the cotyledons; the second term simply means beneath the cotyledons. Compare *epicotyledonary*.

Hypodermal, within or beneath the epidermis.

Hypogenous flower, having the other parts of the flowers inserted on the torus beneath the gynœcium. Compare *epigynous*, *perigynous*.

Hyponasty, the state of growing more vigorously on the under than on the upper surface or side. Compare *epinasty*.

Hypophysis. In Angiosperms, the cell in the undifferentiated embryo body from which the primary root and its root cap are derived.

Hypothecium. In Fungi, the layer or portion of hyphal tissue immediately beneath the hymenium. Same as *sub-hymenial layer*.

Hypsophyll, or hypsophyllary leaf, bract.

Imbricate, overlapping the edges of one another.

Imparripinnate leaf, a compound pinnate leaf with a single leaflet at the apex.

Incised, cut into considerably.

Indefinite andrœcium, when the stamens are more than twelve in number.

Indefinite inflorescence. An inflorescence, the branching of which is either of the elongated or contracted racemose monopodial type. Roughly, a flower cluster in which the youngest flowers are at the top or in the centre. Compare *definite*.

Indehiscent, not opening naturally to allow the contents to escape. Compare *dehiscent*.

Indigenous, native.

Induplicate ptyxis, with the edges turned inwards.

Indusium, the outgrowth of a leaf covering or surrounding one or more sporangia. The integuments of the ovule appear to correspond (in a sense) to the typical indusia of Ferns.

Inferior ovary. The ovary of an *epigynous flower* (*q. v.*) Compare *superior ovary*.

Inflorescence, the branching and other common characteristics of a flower cluster, such as the relative lengths of the axis of inflorescence and presence or absence of flower stalks.

Innate anther, attached by its base to the very apex of the filament.

Insertion, the place and mode of attachment of an organ to its support.

Interfascicular cambium, that part of a cambium ring lying between the primary vascular bundles. Compare *fascicular cambium*.

Internode, the part between two nodes.

Intine, the *endosporium* or inner cellulose coat of a pollen grain (*q. v.*) Compare *extine.*

Introrse anther, with the loculi, and consequently the dehiscence towards the centre of the flower. Compare *extrorse.*

Intussusception, growth by the intercalation of molecules between pre-existing molecules. Compare *accretion.*

Involuce, a whorl or closely applied whorls of leafy bracts.

Involucel, a small involucre or leafy involucrate cup surrounding the base of a single flower of an involucrate inflorescence.

Involute ptyxis, rolled inwards from both edges.

Irregular flower, one having the parts of its most prominent floral envelope (or whole perianth if double and similar) unequal in size. Compare *regular flower.*

Isogamous, conjugation in which the coalescing gametes are similar in appearance. Compare *oogamous.*

Isomerous, applied to the whorls of a flower when each contains the same number of parts. See *eucylic.*

Isostemonous andrœcium, when the stamens of a flower are equal in number to the petals and to the sepals, or to the latter only in single perianthed flowers. Compare *anisostemonous.*

Karyokinesis. In common bipartition of cells, the behaviour of the nucleus previous to its perfect division.

Labellum. In Orchidaceæ, the odd enlarged and irregularly shaped petal. Its anterior position is due to the torsion of the elongated ovary.

Labiate, two-lipped.

Lamella. In Hymenomycetes, vertical plate of hyphæ on the under side of the pileus along the exterior of which the hymenium is developed.

Lamina, blade of leaf.

Leaflets, the separate blade portions of a compound leaf.

Leaf-trace, the common vascular bundles of a stem which bend out into a leaf.

Legume, a dry monocarpellary fruit dehiscing by both sutures (*dorsal* and *ventral*).

Leptosporangiate, bearing sporangia, each of which was formed from a single epidermal cell. Compare *eusporangiate.*

Lid-cells of archegonium, the terminal cells closing the entrance to the neck of the immature archegonium.

Ligule, a stipule or foliar appendage arising from the base of the lamina, but always above the insertion of the leaf.

Limb of petal, lamina.

Lipoxeny, alternation of parasitic with non-parasitic existence, *i.e.*, desertion of host. Compare with *autoxeny*, *metoxeny.*

Loculi (*sing.* loculus), the chambers of an ovary or anther which are normally produced to contain in the former seeds, and in the latter pollen. An ovary may be unilocular (or one-chambered), bilocular, trilocular, or multilocular.

Loculicidal dehiscence, applied when the splitting of the pericarp of a syncarpous fruit is along the median dorsal lines or sutures of the carpels.

Lodicules. In Gramineæ, minute scales, representing a perianth, inserted under the ovary of the flower.

Lomentum, a legume which has developed spurious transverse dissepiments.

Macrosporangium, sporangium containing *macrospores*. Same as *megasporangium*. Compare *microsporangium*.

Macrospore, the relatively large spore of heterosporous species which gives rise to the female prothallium, or (in Angiosperms) to the antipodal cells and egg apparatus. Same as *megaspore*. Compare *microspore*.

Male flower, having stamens but no gynœcium.

Medullary rays, radially elongated bands of parenchyma of small height running transversely through the stems of Gymnosperms and Dicotyledons. There are two kinds—*primary*, extending from pith to periphery; *secondary*, all others transversely, shorter than the primary and younger.

Medullary sheath, the cylinder of protoxylem immediately surrounding the pith of a stem which has commenced secondary thickening by means of a cambium ring.

Megasporangium and Megaspore, same respectively as *macrosporangium* and *macrospore* (*q. v.*).

Mericarp, achene or nutlet of a schizocarpous fruit.

Meristem, dividing cell tissue.

Mesocarp, middle portion of the pericarp.

Mesophyll, the ground tissue of the blade of a leaf.

Metœcious, pertaining to *metoxeny*. Same as *heterœcious*.

Metoxeny, see *heterœcism*.

Micropyle, the rounded aperture in the integuments leading to the apex of the nucellus of the ovule.

Microsporangium, sporangium containing *microspores*.

Microspore, the relatively small spore of heterosporous species, which gives rise to the male prothallium, or its rudimentary representative (prothallus cell) in Phanerogams. Compare *macrospore*.

Midrib, the chief vein or portion of the leaf-blade from which the other principal veins branch off.

Mon or Mono, in composition, *one*.

Monadelphous stamens, when *all* the stamens of a single flower are united by their filaments into one bundle. Compare *diadelphous*, *polyadelphous*, *syngenesious*.

Monocarpellary, composed of one carpel. Compare *polycarpellary*.

Monochlamydeous flower, with a single perianth only. Compare *dichlamydeous*, *achlamydeous*.

Monoclinous, same as *hermaphrodite*.

Monœcious, when distinct male and female, but no hermaphrodite flowers are borne on the same plant. Compare *diœcious*.

Monopetalous, same as *gamopetalous*.

Monopodium, an axis which continues to grow in one direction at the apex, and produces branches in acropetal succession behind the growing point.
Monosepalous, same as *gamosepalous*.
Mycelium, the vegetative hyphæ of Fungi spreading in, or on, the substratum.

Napiform, turnip-shaped.
Nectary, any organ connected with a flower secreting nectar, *i.e.*, a sugary fluid.
Nodes, the portions of a stem from which the leaves spring.
Nucellus, the body of the ovule containing the embryo-sac.
Nut, just a large achene (*q. v.*) with a sclerenchymatous pericarp.
Nutation, movements due to unequal growth.

Obdiplostemonous, applied to an andrœcium in two whorls, when the stamens of the outer whorl are opposite to the petals instead of alternating with them, as is the usual case, and those of the inner whorl opposite to the sepals. Compare *diplostemonous*.
Ochrea, the elongated cylindrical axillary stipule of Polygonaceæ, which sheaths the stem above the insertion of the leaf.
Offsets, short branches next the ground, which take root.
Oogamous, opposite of *isogamous*.
Oogonium, a more or less spherical and simple female sexual organ containing one or more *oospheres* (*q. v.*), which after fertilisation do not form pro-embryos within the cavity of the organ on the parent plant.
Oophore, same as oophyte.
Oophyte, the segment or stage of life cycle bearing the sexual organs. Compare *sporophyte*.
Oosphere, the ovum before impregnation, when it consists of a rounded naked nucleated mass of protoplasm. Compare *oospore*.
Oospore, the ovum immediately after fertilisation, when it has become surrounded by a cell-wall. Compare *oosphere*.
Operculum, lid of capsule in Musci.
Orthotropous ovule, one in which the nucellus is straight, and has its base towards the placenta. Compare *anatropous*, *campylotropous*.
Ovary, the lower expanded portion of the pistil which forms and contains the ovule.
Ovate, shaped like an egg with the broader end downwards.
Ovule, the macrosporangium of Phanerogams.

Palea. In Filices, a flat scaly outgrowth of the epidermis; same as *chaff-scale* and *ramentum*. In Compositæ, a bracteole. In Gramineæ, an inner bract subtending a single flower.
Palmate leaf, a leaf with a blade about, at least, as broad as long.
Palmatifid leaf, a palmate leaf with the blade cut from a third to about half way in towards the midrib.
Palmatipartite leaf, an almost compound palmate leaf.

Panicle, a more or less compound raceme.

Papilionaceous, the æstivation of the irregular corolla in tribe Papilionaceæ (Leguminosæ), in which there is a large upper petal, the *standard* that embraces the others in the bud, namely, the two lateral petals or *wings*, and the two ventral petals or *keel*, so called because they are more or less coherent by their lower margins.

Pappus, the tuft of hairs or scales representing the calyx in many Compositæ.

Paraphyses, sterile filaments or narrow plates of cells accompanying sporogenous or sexual organs.

Parasite, an organism living on the substance of another living organism, known as the host.

Parenchyma, cells rounded, polygonal, stellate, brick, or lath-like, in form ; never with pointed overlapping ends. Typical parenchyma always contains protoplasm. Compare *prosenchyma.*

Parietal placentation, when the ovary is unilocular or spuriously bi- or multilocular, and the ovules spring from the coherent margins of the carpel or carpels composing it. Compare *axile* and *free central placentation.*

Parthenogenesis, the developing of the ovum into the normal product of fertilisation without a preceding sexual act.

Pedicel, the stalk of each particular flower of an inflorescence.

Peduncle, a general name for the flower stalk, whether of a single flower or of a flower cluster.

Peltate leaf, a leaf having the petiole attached to the blade within the margin of the latter. The blade is also expanded at about right angles to the petiole.

Penta-, in composition, *five.*

Pepo, a berry with a hard, firm, or leathery pericarp, as Cucumber.

Perennial, lasting from year to year.

Perfoliate, applied to a leaf, or stipules which surround the stem like a collar.

Perianth, floral envelope. It may be single or double ; if the latter, both whorls are either similar or dissimilar.

Periblem, the meristematic strands of cells between the plerome and dermatogen (*q. v.*), just behind and leading from the apical initial cells of the stem and root. Same as *primary cortex.*

Pericarp, the mature wall of an ovary.

Perichætium, the envelope of leaves surrounding a group of sexual organs in Muscineæ.

Periclinal walls are those running in the same direction with the periphery of a part. Compare *anticlinal.*

Periderm, the cork cambium and the tissue of cork cells produced by it.

Peridium. In angiocarpous Fungi, the complete investment of the sporocarp.

Perigonium. In Musci, the perichætium of the group of male organs in monœcious or diœcious plants.

Perigynium. In Hepaticæ, special envelope of the archegonium.

Perigynous flower, a flower with the *torus* (*q. v.*) hollowed into a shallow or deep open cup. Compare *hypogynous, epigynous.*

Periplasm. In Peronosporeæ, the peripheral protoplasm of the antheridium (pollinodium) and oogonium, which does not share in the act of conjugation. Compare *gonoplasm.*
Perisperm. In seeds, a storing tissue outside the embryo-sac, and derived from the nucellus.
Peristome, the series of teeth round the mouth of the open capsule of many mosses.
Perithecium, same as *pyrenocarp* and *cleistocarp.*
Petal, leaf of corolla.
Petaloid, coloured like a typical petal.
Petiole, stalk of leaf.
Phanerogamæ, plants producing seeds. Same as *spermaphyte.*
Phlœm, vascular tissue containing sieve tubes. Compare *xylem.*
Phylloclade, a stem branch which resembles a leaf. Same as *cladode* and *cladophyll.*
Phyllode, a flattened and blade-like petiole.
Phyllotaxis, arrangement of leaves on the stem.
Pileus. In Hymenomycetes, the cap-like summit of a sporocarp bearing the hymenia.
Pinnate leaf, a leaf with a blade distinctly longer than broad. Compare *palmate leaf.*
Pinnatifid leaf, pinnatipartite leaf, correspond respectively to *palmatifid* and *palmatipartite* (*q. v.*), but are pinnate in character.
Pistil, the ovule-bearing organ of the flower, consisting essentially of *ovary* and *stigma*, with or without a style. It is composed of one carpel, or two, or more. In the latter case it always constitutes the whole of the *gynœcium;* in the former there are as many separate pistils in the gynœcium as there are carpels.
Placenta, the tissue from which the sporangia arise in Vascular Cryptogams. In Phanerogams, that only from which the macrosporangia (ovules) originate is usually so named.
Placentation, disposition of the placenta (Balfour).
Planogamete, same as *zoogamete.*
Plasmodium, a mass of naked amœboid multinucleate protoplasm.
Plerome, the axile meristematic strands of cells just behind and leading from the apical initial cells of the growing point of a stem or root.
Pleurocarpous. In Musci, species in which the archegonia are borne not on the summit of the primary, but on the extremities of branch leafy axis of the first or second order. Compare *acrocarpous.*
Plicate ptyxis, plaited.
Plumule, the primary leaf bud of an embryo plant.
Pluri-, in composition, many or several.
Polar nuclei, the two nuclei which coalesce to form the secondary nucleus of the embryo-sac.
Pollen grain, microspore in Phanerogamia.
Pollen-sac, microsporangium in Phanerogamia.
Pollination, the dusting of the stigma, or in Gymnosperms the receptive surface of the ovule, with pollen.
Pollinium, a coherent pollen mass.

Pollinodium. In Ascomycetes, a male sexual organ which conjugates directly or more usually by means of a tubular penetrating outgrowth with the female.

Poly-, in composition, *many*, or *several free*.

Polyadelphous stamens, united by their filaments into several bundles.

Polycarpous, same as *apocarpous*.

Polyembryony, the production of more than one embryo within an ovule.

Polygamous, with hermaphrodite and unisexual flowers on the same, or on different plants of the same species.

Polypetalous, with free petals. Same as *choripetalous*. Compare *gamopetalous*.

Polyphyllous, applied to a single or double similar perianth when the parts are free. Compare *gamophyllous*.

Polysepalous, with free sepals. Same as *chorisepalous*. Compare *gamosepalous*.

Posterior, of a lateral member, the side next the parent axis. Compare *anterior*.

Primary cortex, same as *periblem*.

Primine, outer coat of an ovule when two are present.

Procarp. In Rhodophyceæ and Ascomycetes, a female sexual organ (uni- or multicellular), consisting of a receptive part, the trichogyne, and a lower portion, the carpogonium, in which the protoplasm is not rounded off to form an ovum like that of higher plants, but which is similarly excited by impregnation to a process of growth resulting in a sporocarp.

Procumbent, trailing on the ground.

Proembryo. In Vascular Plants, the product of the development and division of the fertilised ovum (oospore) before the differentiation of the embryo.

Promycelium. In Uredineæ and Ustilagineæ, a short tubular outgrowth of a spore in germination, which forms and detaches a small number of spores (sporidia) unlike the parent, and then dies.

Pronucleus, the nucleus of a gamete which, after coalescence with another nucleus in conjugation, forms the germ-nucleus.

Prosenchyma, dead elongated cells, with pointed over-lapping ends.

Protandry, maturity of the stamens before the gynœcium in a hermaphrodite flower. Compare *protogyny*.

Prothallium, a thalloid *oophyte* (*q. v.*).

Protogyny, opposite of *protandry* (*q. v.*).

Protomeristem, primary meristem.

Protonema. In Muscineæ, a filamentous or plate-like structure, upon which the sexual generation (conspicuous plant) arises as a lateral or terminal shoot.

Protophlœm, first formed phlœm in a vascular bundle arising from procambium strands.

Protoxylem, first formed xylem in a vascular bundle resulting from the conversion of procambium.

Pycnidium. In Ascomycetes, special receptacle in which gonidia ("stylospores") are abjointed from sterigmata.

Pyrenoid, same as *amylum-body.*

Pyxidium, capsule fruit, with transversal (circumscissile) dehiscence.

Raceme, an indefinite inflorescence, with a long axis and stalked flowers.

Racemose branching, when the parent axis continues to grow and overtop the acropetally-produced daughter axes.

Radicle, the hypocotyl (*q. v.*) and primary root portion of the embryo.

Ramentum. *See palea* and *chaff-scales.*

Raphe, the so-called ridge-like continuation of the funiculus along the side of an anatropous ovule, and adherent to its coat.

Raumparasite, same as *aulophyte.*

Receptacle. In Phanerogams, the *torus* (*q. v.*).

Receptive spot, the clearish spot in an ovum at which the male gamete enters.

Regular flower, when all the parts of the floral envelope, or most prominent envelope, if two are present, or whole perianth, if double and similar, are equally developed.

Rejuvenescence, the escape of the entire protoplasm of a cell, and its subsequent conversion into a new walled cell of a different character.

Replum, the spurious dessepiment of a siliqua or silicula. It is often defined, however, as the whole frame of such a fruit after the valves fall away.

Rhizoid, a unicellular or pluricellular (usually) filamentous branching outgrowth analogous to a root.

Rhizome, an elongated, more or less horizontal, subterranean stem, sending up annually aerial members.

Rudimentary, imperfectly developed, or in a more or less permanent phase of early development, or degenerated, or but feebly developed ancestral relic.

Samara, winged achene or mericarp.

Saprophyte, a plant which lives on dead and decaying organic matter.

Schizocarp, a bi- or multilocular fruit, which splits up into indehiscent one-seeded portions (achenes or mericarps).

Sclerotium. In Fungi, a resting metamorphosed state of mycelium filled with reserve foods which, after a dormant period, puts forth stalks that develop sporocarps.

Scorpioid cyme, sympodial monopodial branching, in which the successive lateral axes are placed alternately right and left. Same as *cicinus.* Compare *helicoid cyme.*

Scutellum. In Grasses, the broad shield-like cotyledon acting as an organ of suction in the albuminous seed.

Secundine, the coat of the ovule lying next the nucellus.

Seminiferous scale. In Coniferæ, the large persistent outgrowth on the upper surface of the carpel which produces the placenta and ovules.

Sepal, leaf of calyx.

Sepaloid, like a typical sepal.

Septafragal dehiscence, when the pericarp of a plurilocular fruit separates into valves that break away from the dissepiments.
Septicidal, dehiscence through the partitions dividing each into two layers.
Sessile, without a stalk.
Seta. In Musci, stalk of capsule.
Siliqua, a dry dehiscent fruit, composed of two carpels, and having a replum. *Silicula* is a broad siliqua.
Soredia. In Lichens, small groups of algal gonidia invested by hyphæ, which are set free from the parent and grow into new individuals.
Sorus (*pl.* **Sori**). In Filices, group of sporangia arising together from a placenta.
Spadix, fleshy spike.
Spathe, a bract which enwraps an inflorescence or solitary flower, at least when young, if not also when mature.
Spermatium, a non-motile male gamete, which usually conjugates with the trichogyne of a *procarp* (*q. v.*).
Spermatocyte, mother-cell of a spermatozoid.
Spermatozoid, an actively motile ciliated or flagellated male gamete.
Sperm-nucleus, male *pronucleus* (*q. v.*).
Spermogonium, receptacle in which spermatia are adjointed on sterigmata.
Spike, an inflorescence which only differs from a *raceme* (*q. v.*) in having sessile flowers.
Sporangium, a sac producing and containing spores until maturity.
Spore, the true spore is a cell, the direct or indirect result of a sexual act, which becomes free and is capable of developing into a new individual.
Sporidia, spores adjointed on a *promycelium* (*q. v*).
Sporocarp, the true sporocarp is a t.ssue, resulting in consequence of a sexual act, which serves for the production of spores, and dies down after the dispersion of the latter on maturity. It represents the *sporophyte* of higher plants.
Sporocyte, mother-cell of a spore.
Sporogonium, the sporocarp in Muscineæ.
Sporophore, same as *sporophyte*.
Sporophyll, a leaf, normal or modified, bearing spores.
Sporophyte. In Vascular Cryptogams and Phanerogams, the spore-bearing stage or part in a life-history. Same as *sporophore*. Compare *oophyte*.
Spurious dissepiment, septum in an ovary which cannot be regarded as having originated directly or ancestrally from the infolding of the carpel margins, or by the upward growth of the floral receptacle.
Stamen. In Phanerogams, the male sporophyll.
Staminode, abortive or sterile stamen.
Sterigma. In Fungi, stalk from which a gonidium, spore, or spermatium, is abjointed.
Stigma, the receptive surface of a pistil.
Stilogonidia. In Fungi, the gonidia abjointed from sterigmata on a gonidiophore.
Stipes, stalk supporting the pileus of mushroom.

Stipules, appendages at the base of a leaf.
Stolon, a slender shoot running along the surface of the ground.
Stoma, an epidermal structural apparatus, consisting essentially of guard cells, surrounding an intercellular aperture which communicates with the air spaces in the interior of the plant.
Style, the stalk-like prolongation of the complete pistil, supporting or bearing the stigmatic surface.
Suberin, cork.
Sub-hymenial layer. See *hypothecium.*
Superior ovary, the ovary of a *hypogynous flower* (*q. v.*).
Superposed. In a flower, same as *opposite.*
Suspensor, filamentous pro-embryo of Phanerogams and *Selaginella.*
Suture, line of junction, or line of opening.
Swarm-cell, same as *zoogonidium.*
Symbiosis, the living together of dissimilar organisms for mutual benefit.
Symmetrical flower, one having all the parts of calyx, corolla, and andrœcium, equal in number or in the same ratio.
Sympodium, an axis made of the bases of successive axes which have regularly arisen in the order of branching one from the other. Same as *pseudo-axis, false axis.*
Syncarpous gynœcium, one composed of two or more carpels, which are all united together to form one pistil. Compare *apocarpous.*
Synergidæ, the two cells at the apex of the embryo-sac, constituting the rudiment of an archegonium neck, and forming, with the ovum, the egg apparatus of Angiosperms.

Tapetum, a cell, or in its more typical state, a layer of cells immediately outside or surrounding an *archesporium* (*q. v.*), which becomes disorganised as the spores develop.
Tap-root, the primary root produced by the development of the tip of the radicle of the embryo.
Tegmen, inner seed-coat.
Teleutogonidium (teleutospore). In Uredineæ, gonidium formed on, but not separating from, a stalk (sterigma), and giving rise on generation to a promycelium.
Testa, outer seed-coat, or only, if but one is present.
Tetra, in composition, *four.*
Tetradynamous stamens, when in a single flower there are apparently six stamens, four of which are relatively long, and two short.
Thallus, typically a vegetative body, which shows no differentiation into root, stem, or leaf.
Theca, the capsule of Musci.
Torus, the part of a floral axis on which the members of a single flower are inserted.
Trama, the hyphal tissue in the interior of the lamellæ of mushrooms.
Trichogyne, the filamentous receptive portion of a procarp (*q. v.*).

Trimorphism. In flowers, when those of the same species exhibit three different lengths of styles—one flower being short-, another medium-, and another long-styled. See *heterogony*. Compare *dimorphism*.

Tuber, a fleshly-thickened under-ground branch, or end of a branch stem.

Umbel, a variety of *indefinite inflorescence* (*q. v.*) in which the primary axis (axis of inflorescence) is contracted to a point from which the stalks bearing the flowers arise.

Umbellule, the ultimate umbel in a compound umbellate inflorescence.

Uni-. In compound words, *one*, as unilocular, uniaxial, unisexual, &c.

Uniparous cyme, same as *sympodial cyme*.

Uredospore, the unicellular gonidium of Uredineæ which separates by abstriction from the sterigma, on it is formed and produces, on germination, a mycelium bearing uredospores and teleutospores (*q. v.*).

Vaginula. In Musci, the low sheath-like wall formed by the growth of the stem apex round the embedded foot (or basal portion of the stalk) of the sporogonium.

Valvate vernation (or æstivation), meeting like valves at the edges, but not overlapping.

Velum. In Isœtes, the *indusium* (*q. v.*).

Velum partiale. In Hymenomycetes (mushrooms), a tissue membrane extending across from the stipe to the margin of the pileus, and covering the developing hymenium.

Velum universale. In Hymenomycetes, the tissue membrane which envelopes the whole developing sporocarp. Same as *volva*.

Venation, the distribution and arrangement of the veins or fibro-vascular groups in a leaf.

Venter, the lower expanded portion of an archegonium in which the ovum is formed.

Ventral canal-cell, a small cell lying above the unfertilised ovum in the archegonium, which has been divided off from the mother-cell of the ovum during the formation of the latter.

Ventral suture. In Ovary, the line of union of the infolded edges of the carpels. Compare *dorsal suture*.

Vernation, grouping of the leaves in the bud. See *æstivation*.

Versatile, applied to anthers which are attached to the apex of the filament at one point above their base, as in Gramineæ.

Verticillasters, contracted biparous cymose inflorescences in the axils of opposite leaves.

Vexillary, same as *papilionaceous* (*q. v.*)

Vittæ, the oil-ducts or receptacles in the shoots and pericarps of Umbelliferæ.

Woody, feeling hard owing to the development of much wood.

Xylem, portion of a vascular bundle, or of axis with secondary thickening containing tracheæ. Compare *phlœm*.

Zoidiophilous, pollinated by the agency of animals. See *entomophilous.* Compare *anemophilous* and *hydrophilous.*

Zoogamete, a motile gamete. Same as *planogamete.*

Zoogonidium, motile gonidium.

Zoosporangium, a sporangium producing zoospores.

Zoospore, motile spore.

Zoozygospore, motile *zygospore* (*q. v.*).

Zygomorphous flower, a variety of irregular flower, divisible by *one* vertical plane into similar halves. Compare *actinomorphous.*

Zygospore, a spore resulting from the conjugation of two similar gametes.

Zygote, the general term for the product of the sexual coalescence of two gametes, whether similar or dissimilar.

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